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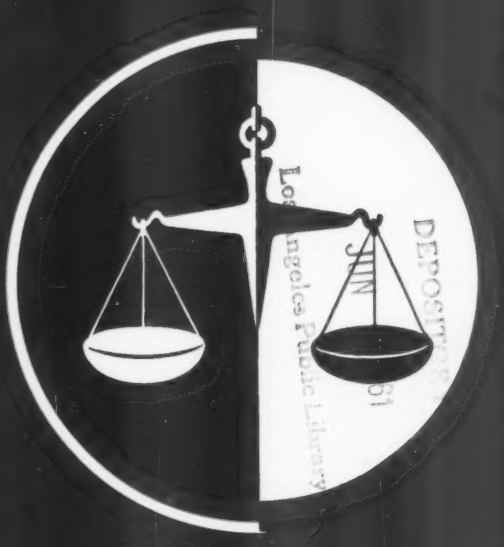

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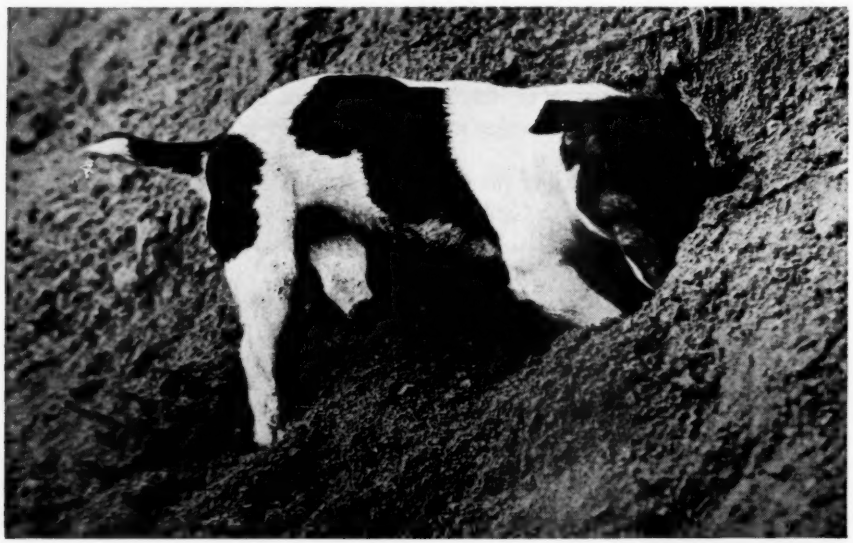

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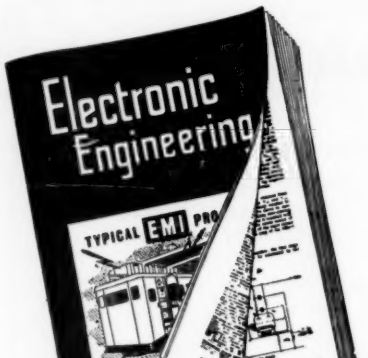

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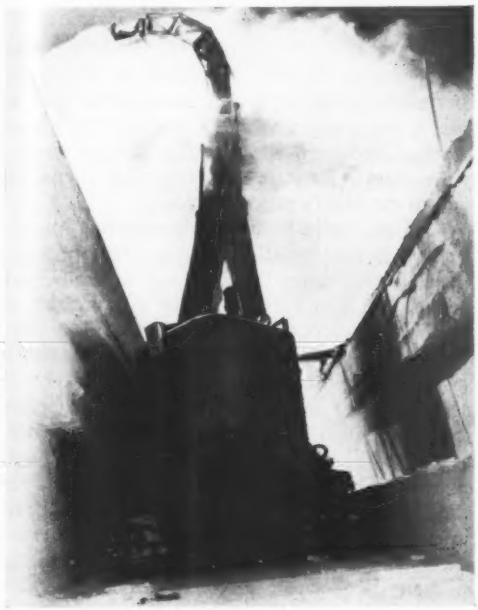
Notes and Comments

Camp Century

More than 100 American scientists and technicians spent last winter in one of the world's strangest towns, newly-built under the Arctic ice-cap. They moved there in October when this strange nuclear-powered town, called Camp Century, was completed.

Camp Century is in Greenland, about 800 miles from the North Pole. It was built by engineers of the United States Army under an agreement between the U.S. and Danish governments.

The scientists there are studying weather conditions in one of the most severe climates on earth. Greenland is the birthplace of weather for much



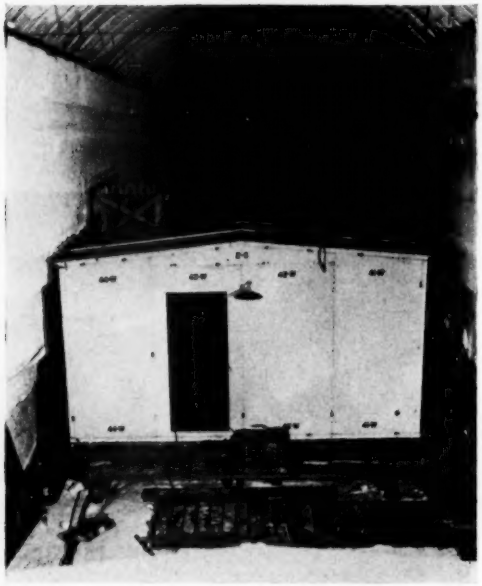
The Peter Snow Miller is the secret of the construction of Camp Century. The machine was developed by the Swiss to plough through snow-clogged mountain passes. It discharges snow overhead through a long chute. Here it is digging a camp street.

This circular hatchway projecting from a desolate Arctic snowfield is one of the entrances to Camp Century. Beneath the snow is a small town.

of the Northern Hemisphere. By drilling deep into the ice-cap, samples of ice formed hundreds, even thousands of years ago can be brought to the surface and analysed—for in the content and structure of these ice samples the history of snowfall and weather for many centuries has been preserved.

Camp Century consists of 21 tunnels in the ice-cap, criss-crossing one another like city streets. Inside these snow tunnels 30 prefabricated wooden buildings have been erected, including research laboratories, living quarters, a water supply system, atomic power plant and virtually every facility needed by a self-sufficient community. Huge garage doors at each end of the main street serve as entrances. There are also escape hatchways in case of a cave-in or other emergency.

The camp was built by digging deep trenches which were then roofed with corrugated steel. The roofing was covered with a blanket of snow which was allowed to harden into ice before the steel roofing was removed from below.



There are thirty buildings like this in the underground camp, including laboratories, living quarters, mess hall, library, laundry, chapel and recreation facilities. To prevent heat from the buildings melting snow walks, ventilation fans draw cold air up through the glacier.

Until now the problem of supplying heat and power under such adverse conditions has been an obstacle to an effective Arctic research programme. At Camp Century this has been solved by installing a nuclear reactor which generates 2000 kilo-watts of electric power and operates for a year on a single loading of fuel. The reactor eliminates the need for hauling across the ice-cap enormous quantities of fuel oil that would be required by a conventional power plant.

Among the tests and experiments to be conducted at Camp Century are: reliable methods of detecting and locating crevasses, the dangerous, hidden crevices which form on the ice-cap; snowdrift studies; deep drilling for ice cores 1000 and more years old; new aerial photo techniques; and of course, constant observation and testing of the facilities of Camp Century itself—for the way in which these 100 men can live beneath the ice-cap is Camp Century's biggest experiment.

In the building of the camp the scientists and technicians have already found solutions to a number of difficulties encountered in this very cold region.

Science Horizons

Eye and Brain

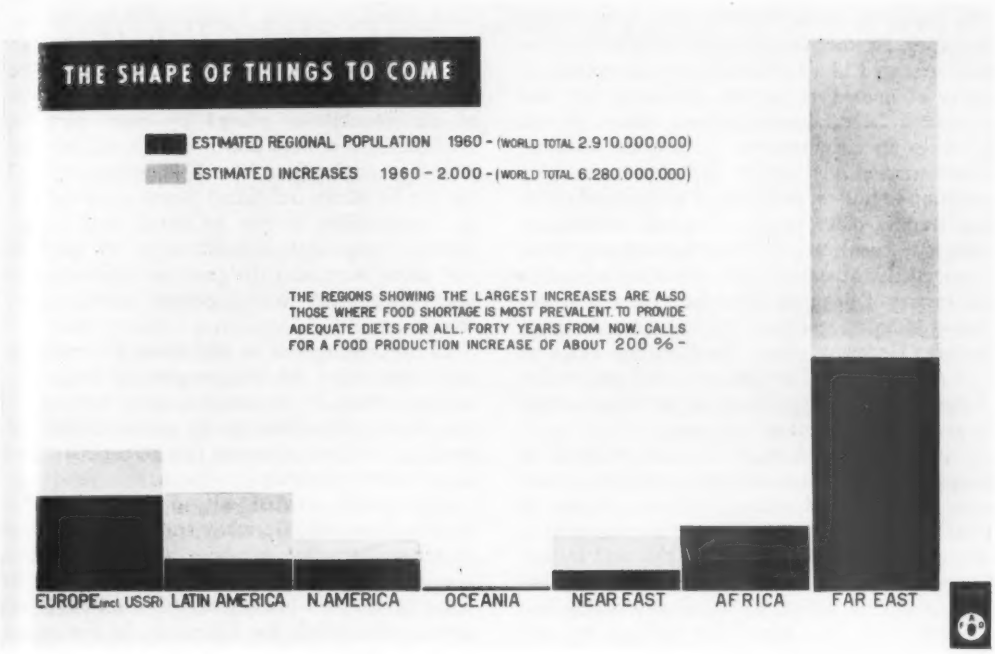
For some years Australian scientists at Sydney University led by Professor P. O. Bishop have been investigating the coding and transfer systems of the human eye. The key to their research is a multi-beam ophthalmoscope which is an advanced version of a machine built some time ago by scientists engaged on similar research at Johns Hopkins University, U.S.A.

The light that enters the eye and outlines the features and nature of the object looked at is transformed by the retina into electrical impulses which travel toward the brain through the optic nerve. Scientists estimate the human optic nerve to be made up of at least a million fibres of differing sizes, but so minute are these fibres that even the closest microscopic examination of them has so far not revealed their exact number.

The retina partly processes these impulses into a code and the impulses pass along the optic nerve to a collection of nerve cells called lateral geniculate, a processing station, as it were, which does the final and complete job of converting the impulses into an intricate code suitable for transmission to the brain's visual centres.

With the multi-beam ophthalmoscope physiologists are able to stimulate the eye with light beams, which make the eye work naturally, and because the light input is known they are able to analyse the reactions of the eye. Tests have been made on humans, but the more detailed research is carried out with cats. The researchers play three beams of light into the cat's eye. As the beams strike the retina and then go through the whole process of becoming coded signals to the brain, electrodes pick up the complex messages of electrical impulses and transmit them into amplifiers. These recorded sounds are fed into an electronic computer which records the code signals in digits printed on sheets of paper, and also attempts to analyse the code.

When completed it is expected that these researches will shed more information, amongst other things, on why the human eye is able to see as a continuous and steadily flowing picture a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Population: the shape of things to come

Sociologists and statisticians predict that the world population will double itself in less than forty years. As the present population numbers more than 2900 million, it is estimated that the figure will rise to about 6280 million by the end of the century. The distribution of this increase over the various regions of the world presents an interesting picture. Europe, including the U.S.S.R., will rise from about 639 million to an estimated 947 million, Latin America from 205 to 592 million, Northern America from 197·6 to 313·5 million, Oceania from 15·7 to 27·8 million, the Near East from 131·4 to 332·4 million, Africa from 93·7 to 420·6 million and the Far East from 1526·3 to 3634 million. This growth is very unevenly distributed over the world and the largest increases in population will take place in those areas where there is already a shortage of food. To feed such populations, man will have to increase his food production by about 200 per cent. It may be said that this is the biggest—and most menacing—challenge which humanity has ever had to face. It involves all people throughout the world and presents a problem that can only be solved through international co-operation.

F.A.O.

International Congress of Dietetics

The Third Congress, which has Lord Boyd Orr as President, will be held at Church House, Westminster, from July 10 to 14, 1961, and will gather together members of Dietetic Associations and allied professions from many parts of the world. An attendance of more than a thousand is expected which is double the number of the 2nd Congress which met in Rome in 1956. The theme of the Congress is Tradition, Science and Practice in Dietetics. This theme will be developed in two opening days of plenary session for the consideration of food patterns from many different countries and the education and

occupations of dietitians in different countries. The papers for these sessions come from sixteen countries. Further international participation has been arranged in a series of discussion groups on topics of immediate interest, including diet and ischaemic heart disease, school meals, recent advances in diet therapy, large-scale catering, administration of a dietary department, teaching nutrition to nurses, nutrition of mother and child, and feeding older people. Original communications have been accepted in the fields of new therapeutic diets, atherosclerosis, nutrition education and history of dietetics. These come from U.S.S.R., Japan, India, Argentina, Czechoslovakia, Hungary, France, Germany, Italy, Switzerland, Belgium, U.S.A. and U.K. The Congress will end with a discourse on the application of research findings to practical problems of nutrition.

During the week visits will be arranged to hospital diet-kitchens, industrial canteens, school meal kitchens and other places of interest to dietitians. Formal or informal entertainment is arranged for most evenings and this will include invitations to overseas members from U.K. members and their friends to spend an evening in a London home. It is hoped that this may help our international visitors to feel at home.

The Congress Proceedings are to be published for issue free to members on registration. The Proceedings will be available to non-members at £3 3*s*. 0*d*. Orders may be placed with Newman Books Limited, 68 Welbeck Street, London, W.1.

Wind Power

In the past, the practical use of wind energy was limited mainly to water pumping stations operated by ordinary multiple-bladed windmills or to small propeller-driven wind-engines with an electric generator of one or two kilowatts, generally used to charge storage batteries. These two sorts of wind-power machines were used, and still are, in areas where there is no convenient electric power supply.

But despite the usefulness of these low-powered wind-driven generators, it was quickly realised that they could never provide an economic large-scale solution to the problem of producing power for underdeveloped countries, and studies were made of the possibilities offered by more powerful machines. Plans were drawn up of medium-sized machines ranging from 30 to 50 kilowatts, designed for use by heavy individual power consumers or by communities served by small local supply systems. Large-scale installations of 100 kilowatts and more were also designed as supplementary plants connected to the general power supply system.

In the development of arid zones, the medium-sized plants show the most promise, for large-scale supply systems rarely exist in areas of low population density. However, the big machines could be useful as a means of saving fuel in regions where such networks do exist.

Experiments carried out in recent years in Britain, Denmark, Germany and France have led to the construction of about a dozen machines ranging in power from 8 to 600 kilowatts. This latter figure refers to the giant experimental wind-power plant which the Electricité de France has built at Nogent-le-Roi near Paris and which, at the present time, is probably the world's most powerful 'windmill'. It consists of a three-bladed propeller 98 ft. in diameter, which rotates at 47 r.p.m. Its horizontal axis is 115 ft. above the ground. It drives a 3000-volt A.C. generator at 1000 r.p.m. This machine is connected to the local power supply system. Tests, which are to cover a period of many months, will provide the basis for a scientific study of the problem. This particular research is aimed mainly at perfecting wind plants designed to feed into a local network rather than plants for individual communities. But the same principles of construction could also be used for the second type of machine.

UNESCO

ECONOMICS FOR THE UNINITIATED

By R. L. SMYTH *Department of Economics, University College of North Staffordshire.*

'Interesting and vital social problems are now essentially political and sociological in character—their economic content is negligible; the future belongs to sociology and politics just as the past belonged to political economy'. 'Because scarcity is the subject matter of economics it has lost touch with a society whose members have been inundated with goods and bewildered by leisure'. 'Economics survives merely because it provides mental gymnastics which have been substituted for Latin and Greek'. These are a few examples of the complaints which are made about economics. Are they justified? Is it right and proper that so many people study, teach and practise economics? In this short article I will say something about recent developments in various branches of economics in an attempt to permit the subject to speak for itself. Unless economic theory truly reflects the realities of the economic aspects of contemporary society, then both theoretical and applied economics are indeed in a sorry state.

Keynesian Economics

We may begin with the major reconstruction of economic theory which was undertaken in the middle 1930s; it was in large measure the work of one man, John Maynard Keynes (Lord Keynes). Before then economic analysis consisted of a theory of value and distribution—which provided a fairly comprehensive explanation of prices including wages, interest, rents and profits—and, in addition, theories of money and banking, industrial fluctuations, public finance and international trade. The New Economics of the 1930s, now usually referred to as Keynesian Economics, welded together into one general theory the hitherto separate bits and pieces of money and banking, industrial fluctuations and public finance. Keynesian Economics has now flourished to such an extent that it is taught in many schools in preference to value and distribution, or even that old favourite the economics of industry.

Keynesian economics is about income flows: their interrelationships and the factors which cause the various income flows to change. If we abstract from external trade, then the total output of an economy is destined for either consumption or investment (capital formation); and total income, which must be equal to total output, is either spent on consumption or saved (not spent). It follows that savings must equal investment. Consider now two sets of circumstances: (1) A fall in investment expenditure. This will directly reduce the amount of income earned in the investment sector of the economy and indirectly reduce the expenditure on the consumption sector. Total income will fall by an amount greater than the initial fall in investment and this will cause savings to fall (as income falls it becomes increasingly difficult to save); the consequence will be savings equal to investment at a lower level of income than we started from. This is the mechanism of depression. Given a stable relationship between income and consumption then the magnitude of the decline in income following upon a fall in investment can be predicted. (2) A rise in investment in a situation where the resources of the economy (land, labour and capital) are fully employed. This will expand the demand for resources in both the investment and consumption sectors of the economy beyond available capacity and prices will tend to rise. This is the mechanism of inflation. The rise in prices cuts back consumption until savings once again equal investment.

Of course slumps and booms are always much more complex than this; recently in Britain we

even experienced inflation while the economy was operating below capacity. Nevertheless, the model lays bare the bones of the economy, and the construction of more elaborate models is, in consequence, greatly facilitated.

The theory has been elaborated to embrace international trade. The income flows generated by exports operate in a similar way to those generated by investment, and imports, like savings, tend to rise and fall as income moves up and down. Thus excessive expenditures on investment and consumption may result in a balance of payments deficit because the high levels of income 'suck-in' imports and output intended for export will be retained at home; not infrequently inflation and balance of payments difficulties occur together. In an open economy domestic savings must be equal to domestic investment plus the difference between the values of exports and imports. It follows that if domestic savings should be less than domestic investment then there would be a deficit in the balance of payments which would be financed by borrowing from abroad. The analysis emphasises the important part played by savings in sustaining stability in a full employment economy.

Of course relating the various income flows to each other is merely a beginning. We also must know about the factors which influence families and firms when they decide how much to spend on consumption and investment and the forces operating at home and abroad which determine exports and imports. Fortunately Keynesian economics is essentially a reformulation of economic theory and not a complete break with the past; it derives much of its strength from being based on a solid foundation of past achievement which comes to our aid when we delve into the detailed workings of the economy. Overall control of the economy can be exercised by the Government through the banks (monetary policy) and through its taxation and expenditure (fiscal policy). In 1944 the Government white paper on *Employment Policy* contained the following statement: 'The Government accept as one of their primary aims and responsibilities the maintenance of a high and stable level of employment after the war.' This promise could not have been made at the end of the First World War because at that time the necessary co-ordinated knowledge about income flows was not available. Furthermore, without a comprehensive theory of employment it was almost impossible to appraise the effects of changes in money and interest rates on the economy, and control exercised through the budget as we know it today was not even considered.

National Income Accounting

National income accounting has been an invaluable by-product of Keynesian economics. Proper accounting has long been recognised as essential in business, but it was not until 1941 that official estimates of national income and expenditure were produced for this country. National income is explained as follows by the Central Statistical Office: 'The national income is a measure of the money value of goods and services becoming available to the nation from economic activity. It can be regarded in three ways: as a sum of incomes derived from economic activity, which can be broadly divided for example between incomes from employment and incomes from profits; as a sum of expenditure, the main distinction being that between expenditure on consumption and expenditure on adding to wealth (or investment); or as a sum of the products of the various industries of the nation. . . . The analysis of national income statistics is not confined to the subdivision of the national aggregates into the various forms of income, product or expenditure. It extends to the compilation of accounts for particular groups within the nation—the sectors of the economy—and thus throws light on the transactions between the sectors.' A National Income and Expenditure Blue Book is now published each year by the Central Statistical Office and a 370-page guide is available which explains the conventions on which the accounts are based and the extent to which figures are estimates or informed guesses. The availability of official up-to-date estimates of income flows is of immense benefit. Not only do they set limits to speculation about what has been happening, they also permit investigations into particular sectors of the economy, e.g. road construction, hire purchase, housing, to be related in a meaningful way to the national problems of output, employment, balance of payments, public finance, etc.

Input/Output Analysis

Allied to national income accounting is input/output analysis. An input/output table displays as

fully as possible those 'intermediate transactions which disappear in reckoning the aggregates normally used in national income and expenditure statistics'. An input/output table would show, for example, the extent to which the agricultural sector of the economy depends for its output upon the input from the motor industry, the oil industry, the chemical industry, the building industry, etc., and the extent to which the food industry, the textile industry, etc., depend for their input upon the output of agriculture. A table which shows the extent to which each industry depends upon the output of all other industries for input and how imports, taxation, etc., are distributed between industries and the contribution of each industry to consumption, capital formation, exports, etc., contains a lot of data.

Furthermore, industries (e.g. engineering, metal manufacture, chemicals, textiles, building, transport, etc.) can, with advantage, be subdivided and so can exports and imports into types of materials and products and countries of origin and destination; as sectors proliferate, so data are piled upon data and statisticians and printing presses are kept busy. The mass of data required has tended to discourage workers in this field. However, now that electronic computers are available the sheer mass of data to be processed is attracting large numbers of economists and statisticians into input/output studies. Once an input/output table has been constructed it is possible to estimate the probable effects of expansion or contraction in one sector or sectors of an economy upon other sectors. The simplest way to do this is to assume that the relationships observed in one year will not change in subsequent years and that the relationships between the variables are linear. For example, we may wish to discover the probable impact of a twenty per cent increase in motor vehicle production upon the metal and engineering trades or the proportion of coal output which is indirectly exported in the form of manufactured products. Obviously this work has important practical implications for prediction and economic planning. But the insight to be gained into how an economy really works from constructing input/output tables must be counted as a contribution to knowledge which requires no immediate practical applications for its justification.

In the Soviet Union it is not sufficient to understand how the economy operates, it must also be operated. One would therefore assume that in Moscow there are thousands of economists and statisticians working night and day upon the input/output implications of the production targets laid down by the State Planning Committee. While this is a likely development, until now, apparently, economic planning has consisted of output targets for key sectors of the economy, and as production bottle-necks inevitably arise they are either ironed out or endured. While this technique of planning is both wasteful of resources and often frustrating for consumers and producers, nevertheless it is simple and spectacular results have been achieved.

At the 1960 British Association meeting in Cardiff, Mr. W. B. Reddaway, Director of the Department of Applied Economics, Cambridge University, talked to the Economics Section about economic planning in India. He stressed the importance of a knowledge of input/output relations for Indian planning and the relative unimportance of national income estimates. It is the orders of magnitude of certain key relationships and not precise measurements which are important. The necessary relationships between the growth of light industry and the output of basic industries and the size and composition of stocks of raw materials, etc., must be foreseen. As the standard of living in India rises and population increases so will the demand for food increase beyond what can be supplied from domestic sources. Exports will be needed to pay for imports and, as there will be no food to spare for export, India must instead export manufactured commodities, and, in order to reduce the need for exports, the home production of food must be increased. Similarly it would not be possible for India to depend to too great an extent on imported supplies of basic raw materials and fuels, these must be developed from domestic sources, and quickly. Steel plants in India, supported by their ancillary transport services and based on advanced technology, are essential; they are not as has sometimes been claimed a waste of resources which should have been devoted to developing handicraft industries. A proper balance must be maintained over time in India between light and heavy industry and agriculture. Because of India's dependence on imports appropriate input/output relations must be sustained; this is in

sharp contrast to the Soviet Union where planning mistakes would not lead to a chronic balance of payments situation.

Problems of Growth

The references to the Soviet Union and India introduces the concept of growth. Keynesian economics has been criticised because it is unduly static. In this respect it was conditioned by historical factors. In the 1930's Keynes, and Beveridge, wrestled with the scourge of unemployment. The problem of the growth of output was of secondary importance. Since 1945, however, following upon the abolition of mass unemployment, economists have increasingly been concerned with problems of growth. This is, of course, not a new problem for economists. It was the central theme in both *The Wealth of Nations* (1776) and *Das Kapital* (1867), to mention but two of the classic texts. The classical economists devoted a lot of attention to how best an economy could achieve a surplus over 'subsistence' which would be used for capital accumulation. Recent work on the economics of growth falls under four main headings:

(1) The conditions for maintaining a rapid and steady rate of growth of output in the United States, Britain, Canada, Japan, etc.

(2) Promoting growth in underdeveloped countries, e.g. India, China, Brazil, Nigeria, etc.

(3) Historical studies of industrialisation in various countries.

(4) Trade, capital movements and migration between developed and underdeveloped countries.

Under the first heading there have been attempts to bring Adam Smith, Ricardo, Marx, Mill, etc., up to date. Joseph A. Schumpeter (1883–1950) 'was the first among modern economists to cut out economic development as a specialised area of economic analysis'. The vision and originality displayed in Schumpeter's writings, which culminated in *Socialism, Capitalism and Democracy* (1942), are such that he challenges Keynes for the title of the outstanding economist of the last generation. Many of the models of growth take as their starting point the short-run model of the economy presented by J. M. Keynes in *The General Theory of Employment, Interest and Money* (1936) and attempt to project it into the long-run. This was first undertaken by Sir Roy Harrod in his writings on 'Dynamic Economics' which initiated new ways of thinking about the growth problem. There is general agreement about the factors which are of paramount importance in economic growth: savings and capital formation which are intimately connected with the distribution of income between wages and profits; technological and other developments which result in innovations; and population growth. But, understandably, a theory which contains the essence of the growth of nations and which embraces or rejects all competing theories has yet to appear. However, it seems inevitable that a new and fairly comprehensive theory of growth will be forthcoming soon.

Professor W. A. Lewis in his admirable book *The Theory of Economic Growth* has stated that 'The central problem in the theory of economic growth is to understand the process by which a community is converted from being a 5 per cent to a 12 per cent saver'. When we consider that the 5 per cent savers (the underdeveloped countries) account for over 60 per cent of the world's population and only some 25 per cent of the world's income, it is abundantly clear that, in the world as a whole, serious economic problems are increasing and not diminishing. Underdeveloped countries are of many different types and each displays unique problems. But they have one thing in common—their institutions differ so radically from those of developed countries that economic theory which is relevant to the latter sometimes fails to make sense in the context of the former. For example, the responses to price and income changes, which may be taken for granted in developed countries, may not operate in countries with different customs and attitudes, and, while in developed countries unemployment may be caused by ineffective demand, in underdeveloped countries it may also be caused by a lack of capital. The way in which 'bourgeois' and 'marxist' economics have been modified to conform with the institutions of underdeveloped countries is impressive. Economists in both types of countries have contributed to these changes and numerous excellent surveys have been undertaken by teams of economists, sociologists, anthropologists, psychologists and geographers working in close collaboration in the various countries.

The world food and population problem centres upon the underdeveloped countries. Its economic

and other aspects were admirably surveyed at the Cardiff meeting of the British Association (August 31 to September 7, 1960).

Industrial Revolutions

An approach which has increased our understanding of contemporary underdeveloped countries is detailed studies of the industrial revolutions in Britain, France, Germany, U.S.A., Japan, Turkey, Russia, etc. These studies aim at elucidating the reasons for their so-called 'Take-offs' and subsequent developments. Professor W. W. Rostow in his recent book *The Stages of Economic Growth* claims that 'it is possible to identify all societies, in their economic dimensions, as lying within one of five categories: the traditional society, the preconditions for take-off, the take-off, the drive to maturity, and the age of mass-consumption'. However, applying the lessons of the past to the present is not easy. The countries which first became industrialised enjoyed the advantages of vast tracts of almost unpopulated and fertile land beyond their borders which provided cheap food and raw materials for workers and workshops. Today developing countries have to contend with advanced countries well established in world markets.

We have already seen that India must develop a large export trade if its plans for industrialisation are to succeed and other industrialising countries are in a similar position. But, unless underdeveloped countries possess oil or ores it is exceedingly difficult for them to earn the foreign exchange to pay for essential imports. Advanced countries prefer to subsidise farmers and limit their food imports, and they are reluctant to permit free importation of textiles and other manufactured articles which can most readily be produced by industrialising countries for export. Also the flow of capital and aid from advanced countries is inadequate to compensate for the low level of trade. The inadequacies of world trade have tended to be obscured by the vigorous growth of trade and capital movements between the industrialised countries in recent years.

In a paper presented to the Sociology and Economic Sections at Cardiff, Professor Brinley Thomas drew attention to the changed pattern of migration which has developed recently. Whereas in the past it was mainly from developed to underdeveloped countries, and worked on the whole to their mutual advantage, now migration tends to be restricted to movements between the developed countries, except for a 'perverse' movement of skilled and professional workers from the underdeveloped to the developed countries.

The Theory of Value

Between 1880 and 1930 value and distribution, garnished by some money and banking and industrial and commercial studies, was economics, but now this branch of economics tends to be overshadowed by the economics of employment and growth. Nevertheless in the past thirty years the theory of value and distribution has been reformulated and extended. The theory of value was developed as a theory of competition. The theory demonstrated how market forces co-ordinated the outputs of the numerous firms and how prices were determined by the system and could not be influenced by any one person or group of persons. Also the system guaranteed that the prices charged to consumers equalled the costs of producing commodities in the most efficient way. If consumers wanted more of one commodity and less of another then competition would quickly translate the change in expenditure into appropriate changes in the pattern of production. There was also a theory of monopoly which demonstrated how output and price were determined when a commodity was supplied by only one firm. Under monopoly the supply of the goods would be restricted, prices would exceed the costs of production and monopoly profits would be earned by the owners of the firm at the expense of other members of the community. Hence competition was considered to be both typical and a good thing, and monopoly a rare occurrence and, on the whole, undesirable.

Recent developments in the theory of value have tended to concentrate on ways and means of combining competition and monopoly into one general theory of imperfect or monopolistic competition. In the process there has been a gradual change of attitude by economists to both competition and monopoly. Monopoly elements may contribute towards improvements in technology and the introduction of new products and monopoly may be a necessary element in the full exploitation of production and selling economies,

while competition may lead to procrastination and wasteful deployment of effort.

The Restrictive Practices Court will listen to one economist condemning restrictions placed on competition and another, possibly equally eminent, economist defending the same restrictions. This is not because 'economists never agree', it arises because a balance must be struck, in each instance, between what appear to be the good and bad aspects of monopoly and competition. While economists now tend to speak with less certainty than they did in the past, they perhaps now speak with greater wisdom.

Elegant theories have been constructed by assuming that technology does not change, that consumers' preferences do not change and that products remain constant. But it is well known that businessmen not infrequently introduce new production techniques and redesign their products and direct advertising at consumers to change their preferences or prevent them changing. Recent developments in the theory of value have, in the main, been attempts to emphasise rather than abstract from these aspects of business behaviour. While there has been a gain in realism, there has been a loss of generality; a crop of theories, each one adopted to particular circumstances, has appeared in recent years. Mrs. Joan Robinson, a leading economist who has deserted the theory of value for the lusher pastures of capital formation and growth observed recently: 'A debate which consists in defending or attacking "principles", such as the "full-cost principle", "the marginal principle", or the "normal-cost principle", and trying to fit all types of situation into one system is obviously foredoomed to futility.'

It would be wrong to conclude from the present state of the theory of value and distribution that economics as a discipline lacks coherence. The theory of value is no longer the heart of the matter and it, and the related theories of welfare economics, can be reformulated gradually without work in other branches of economics suffering unduly. In one all-important respect the new and sometimes conflicting theories of value have proved their worth; they have stimulated greater interest in what actually happens inside firms and between firms in particular industries. A large number of books have appeared recently presenting the results of investigations into economic problems in British industries ranging from coal, steel and chemicals to motor vehicles, synthetic fibres and electronics. The investigations of actual business behaviour suggest new theoretical approaches to the problem of price determination. In this context the investigations of C. F. Carter and B. R. Williams into science and innovation in British industry deserve special mention.

The Theory of Distribution

The theory of distribution (profits, wages, rents, etc.) too is in a somewhat unsatisfactory state. This is because this important branch of economics has tended to be neglected. The following observation by an authority on wages and wage theory, Professor John T. Dunlop of Harvard, suggests that in labour economics field work has outdistanced theory: '. . . one of the consequences of improved and enlarged data is that we become less satisfied with existing theoretical systems. The ever-enlarging data challenge the theory at new points and impose new strains on theory. Part of the current dissatisfaction with wage theory arises from ever-increasing factual knowledge of wage rates and the labour market. The new danger of the period is that we shall be so weighted down amd made timid by unique facts and complexity that we fail to discern boldly the general relationships.'

Econometrics

Empirical measurements of mathematical theory, or econometrics, is a branch of economics which is growing fast. It is the branch of economics where the method of approach most closely resembles that of the physical sciences: theories are tested against facts and modified until they conform with the facts or are discarded. Usually multiple regression analysis is used, either to test the validity of theories or to suggest relationships between variables for which theories might be developed. In economics, variables tend to be determined simultaneously, that is to say the direction of dependence is rarely only one way. For example, a rise in investment will increase income which, in turn, may increase investment. It has been found possible to modify regression analysis to take these 'feed-back' effects into account. With the aid of high-speed computers it

is now possible to explore simultaneous relationships in detail, and this has opened up a vast new field for research. Examples of work in this field were presented to the Economics Section of the British Association at Cardiff, by the National Institute of Economic Research (London) and the University of Oxford Institute of Statistics. At Oxford they are building a model of the British Economy: 'The Oxford model is a statistical model; an empirical model; an econometric model —use whatever term you will. A model of this kind consists of a set of equations which postulates the relationships between a number of economic variables and quantifies the relationships by the values of the empirically determined coefficients attached to each variable. It is a model in which theoretical relationships have been tested and adjusted empirically, and in which the relationships are supposed to hold in a statistical rather than a deterministic sense. In other words, the model endeavours to describe the British economy by a set of equations, and to describe it not merely in qualitative, but also in quantitative terms.' It is likely that in time models of this type will be used for forecasting. At London, econometric techniques are being used to improve our knowledge of the process of inflation. Changes in the price level in post-war Britain have resulted from, among other things, changes in demand, import prices, wage rates and productivity, and price changes bring about changes in wage rates. The results obtained by programming and processing quarterly data collected over a ten-year period suggest how much weight should be given to each of the forces which influence the price level.

Whereas most scientific problems are timeless, it might not be meaningful to derive economic relationships from data collected, say, before and after 1939. Allowances can be made for the effects of the passing of time on economic variables, but adjustments render 'facts' something less than facts. The quality and quantity of available data, therefore, must limit to some extent developments in econometrics. Problems which arise because economic and social institutions change over time as well as preferences, commodities and technology, suggest that it is unlikely that econometrics will in time absorb non-mathematical economics, or that economic prediction will become foolproof. However, already within some large firms linear programming is a routine technique of management and the need for more dependable data and precision in postulating economic relationships are but two of the by-products of this flourishing branch of economics.

A New Look at Economics

The following quotation is taken from a textbook which is widely read by undergraduates in British universities: 'Economics is fundamentally a study of scarcity and of the problems to which scarcity gives rise. If there were no scarcity and no need for goods to be shared out among individuals, there would be no economic system and no economists.' In his book *The Affluent Society*, J. K. Galbraith has taken this definition of economics literally and launched an apparently devastating attack on economics and economists: '. . . economic and social behaviour are complex and mentally tiring. Therefore we adhere, as though to a raft, to those ideas which represent our understanding . . . familiarity may breed contempt in some areas of human behaviour, but in the field of social ideas it is the touchstone of acceptability.' Galbraith contends that economists are concerned with problems of scarcity in an Affluent Society which is satiated with goods and services. Production which merely adds to affluence, argues Galbraith, is no longer of paramount importance; indeed through advertising and other types of sales pressure producers create the wants for the goods they produce. But there is much more to economics than merely scarcity. In his *Principles of Economics* (first published 1890, Eighth Edition 1920) Alfred Marshall defined economics as follows: 'Economics . . . is on one side a study of wealth; and on the other, and more important side, a part of the study of man. For man's character has been moulded by his everyday work, and the material resources which he thereby possesses. . . .' This definition of economics, by one of the few men who were really outstanding economists, includes scarcity, but does not exclude everything else; economics is not merely a branch of engineering which attempts to bring about maximum production and consumption from given resources, it is a social science concerned with human beings as well as the volume of production. If it should be accepted that human beings would be 'better off' with fewer possessions

and, presumably, more leisure, both inside and outside the United States, then economics could be modified accordingly. This is no reason for abandoning the subject: the economic problems of affluence are much too fascinating for that to happen—'If everyone has a car, and no room to drive it, no one can enjoy a car. If everyone has a house in the country, there will be no country. . . .' If the argument of Professor Galbraith, that public provision of goods and services is lagging behind private provision, is accepted, then, if something is done about it, the economic problems of the 60's and 70's will lie more in the field of public finance and less in the private sector of the economy. The content and scope of economics has changed in the past and it is changing now. It is a subject which if it is not largely rewritten in each generation loses its appeal and vitality.

Professor Galbraith's eminently readable book should blow a lot of dust and cobwebs off economics. This is something entirely different from puffing and blowing a house down, although this may have been the intention.

Economics is concerned only with those aspects of human activity which can be brought directly or indirectly into relation with the measuring-rod of money. Psychology, Politics, Law, Geography, and Sociology are other branches of the social sciences which are progressing rapidly, and like economics they are concerned with a part and not the whole of social behaviour. It would be wrong to assume that the newer social sciences will replace economics. On the contrary, their rapid growth increases the need for more knowledge of economic activity. Clearly in the future we must hope for increased co-operation between the social sciences.

There are good reasons for being well satisfied with the progress of economics in the past thirty years, and the prospects for the future are encouraging. Compared with developments in the physical sciences, the achievements in economics have been modest; however, the resources devoted to economics, in contrast to those devoted to the physical sciences, have also been modest.

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THE NATURAL AUXINS OF ROOTS

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Introduction

Roots respond positively to the stimulus of gravity; when displaced from the vertical they bend to direct their growing tips towards the centre of the earth. This positive geotropism of the root is due to unequal growth of its lower and upper sides in the region of most active growth located some 2–5 mm. behind the extreme tip. The pioneer work of Charles Darwin, recorded in 1880 in his book *The Power of Movement in Plants*, revealed that the stimulus of gravity was perceived at the root tip and then transmitted back to the region where the unequal growth and hence the curvature occurred. However, not until the studies of geotropism in roots by the Russian plant physiologist, N. Cholodny, from 1924 onwards and the contemporary work of F. W. Went at Utrecht on the responses of the first leaf (the coleoptile) of the oat seedling to light and gravity, did there emerge a general hypothesis of tropisms. This hypothesis postulated the secretion at the root tip and at the coleoptile tip of a growth hormone or auxin which, moving backwards, controlled the expansion of the young cells of the zone of most active growth in length. The effect of gravity on the horizontally placed organ was regarded as a consequence of a diversion of the natural auxin away from the upper and towards the lower side. This uneven distribution of the auxin on reaching the growing region of the coleoptile would cause the upper side to grow less and the lower side to grow more. Hence, the coleoptile curved upwards. A similar uneven distribution in the root had the reverse effect and the root curved downwards. To explain the opposite responses of the shoot and root it was postulated that whereas the normal auxin supply reaching the expanding cells of the coleoptile and of other shoots was below their optimum supply, that reaching the root cells was, by contrast, normally above their optimum. Raising the supply in the case of the shoot cells or lowering the supply in the case of the root cells enhanced growth; the cells in the lower part of the coleoptile or in the upper part of the root were those whose growth was enhanced by diversion of the auxin towards the lower side following geotropic stimulation.

The important postulates of the Cholodny-Went hypothesis as applied to the root were, therefore: (*a*) the root tip produces an auxin similar to, or identical with, that secreted by the coleoptile tip of grasses and this controls the expansion of the root cells, (*b*) the growing root cells as a result of this secretion contain auxin at a concentration above the optimum concentration for their growth (at a *supra*-optimal concentration), (*c*) geotropic stimulation causes the cells in the upper part of the root to receive less auxin and those in the lower part to receive more auxin than normal, (*d*) in consequence, the cells in the upper part of the root receive auxin at more nearly the optimum concentration and their growth is enhanced, while the cells in the lower part receive a still more markedly supra-optimal concentration and their expansion is further retarded.

This hypothesis was supported by Cholodny's contention that the immediate effect of removing the root tip was to cause a temporary enhancement of the straight growth of the root. Reheading the root stumps with freshly excised root tips and particularly with coleoptile tips was at the same time reported to depress the growth of the root. These results initiated the idea that root cells normally receive a supra-optimal amount of auxin; cutting off the source of auxin (the root tip) caused the auxin concentration in the region of cell expansion to decrease and for a time to become more nearly optimal for root growth. A number of later workers, while confirming the importance of the root tip for geotropic sensitivity were, however, unable to obtain any consistent stimulations of root growth immediately following decapitation.

For instance, Younis (1954) in her careful experiments with broad bean roots, reported that no stimulation followed decapitation of roots at 0·5 and 1·0 mm. behind the root apex, while removing a 2·0 mm. tip caused an immediate and significant retardation of growth. Still further doubt regarding the Cholodny-Went hypothesis is raised by the recent observation (Audus and Brownbridge, 1957) that during geotropic curvature *both* sides of the root grow slower than normal. Such data adverse to the Cholodny-Went hypothesis leads us to question all its postulates. Does the root tip secrete a single auxin and if so, is this identical with that controlling the growth of shoot cells? Do root cells obey Went's dictum 'no auxin, no growth'? What aspects of root growth, development and movement are controlled by auxins?

New approaches to the study of the hormonal control of root growth have developed from the application of paper chromatography to the separation of natural growth-active substances and from studies of the growth of excised roots in sterile culture. It is the purpose of this article to consider briefly how far these most recent researches have provided answers to the questions posed above.

The Occurrence of Auxins in Roots

Went, in 1928, described how young oat coleoptiles cease growth when appropriately decapitated and how their growth can be restored by placing the excised coleoptile tips back in position or how they can be caused to develop a growth curvature by placing the excised tips back excentrically (to one side of the cut surface of the coleoptile stump). If the excised coleoptile tips were placed cut surface downwards on agar jelly then the growth-promoting stimulus, the auxin, passed from the tip into the agar and blocks of this agar then acquired the property, when placed excentrically on coleoptile stumps, of inducing, like the tips themselves, a growth curvature. Further, the extent of curvature induced in the coleoptile stumps was shown to be, under standard conditions, proportional to the auxin concentration present in the agar jelly. These observations formed the basis of the first biological assay of auxin activity, the Went curvature test. This was to be used in pioneer studies of the ability of various plant tissues to supply auxin to agar jelly by diffusion or to yield auxin when extracted by organic solvents.

The availability, from 1933 onwards, of β-indolylacetic acid (usually referred to as IAA) (Fig. 1), the demonstration of its activity in the Went curvature test and other subsequently developed biological assays of auxins, and the evidence of its identity with the auxin secreted by the coleoptile tip have made it the standard compound to which all auxin activities can be referred.

Seedling roots were shown to yield, on extraction, material active in Went's curvature test (Thimann, 1934) and isolated root tips to secrete auxin at their cut surfaces which could be collected by diffusion into agar jelly, particularly if the root tips were maintained physiologically active by receiving simultaneously a supply of sugar from the agar (Boysen-Jensen, 1933; van Raalte, 1936). Roots cultured, in appropriate sterile media, from excised root tips and maintained in this way by serial subculture were also shown to contain extractable auxin activity and provided evidence for auxin synthesis in the isolated root system (Nagao, 1937, 1938; van Overbeek, 1939).

The Separation of Root Auxins by Chromatography

These studies mentioned above gave no information regarding the chemical nature of the auxins of roots. Chemical identification could, however, be attempted following the successful application of the technique of paper chromatography to the separation of the growth-active substances of plant extracts by Bennet-Clark and his co-workers at King's College, London in 1952. Paper chromatography separates chemical compounds by virtue of their different rates of movement in a current of water-containing organic liquid (the 'solvent') flowing within a strip of filter paper. The filter paper strip, subsequently dried and freed from the 'solvent', constitutes the chromatogram. The location of compounds on such a chromatogram can be ascertained by examination in ultra-violet light (detection of fluorescent compounds), by spraying with reagents giving coloured derivatives with the type of compound sought or by testing the biological activity which can be washed off sequential segments along the length of the strip. When chromatographed, each particular compound moves a fraction of the distance moved by

the 'solvent' front and such fractions, known as R_f values (e.g. 0·25 meaning a quarter of the length of the chromatogram measured from the starting line) are recorded in reference literature from work with pure compounds and specified solvents. Such R_f values may be a very important guide to the identity of an unknown compound and can also be quoted to characterise growth-active regions of the chromatogram where chemical identity has yet to be established.

Such chromatograms prepared from root extracts have now been assayed for auxins. The auxin assay usually used to determine the activity of eluates from chromatogram segments has been the 'oat coleoptile straight growth test' (Bentley, 1950) which depends upon the enhancement occurring in presence of auxin, of the elongation of isolated segments cut from young dark-grown coleoptiles and suspended in a buffered cane-sugar solution.

The roots to be examined are extracted with chilled alcohol and then the alcohol removed by low temperature vacuum distillation to give an aqueous extract. This is then shaken with ethyl ether or ethyl acetate. When this is done the known plant auxins like IAA and the corresponding β-indolylacetonitrile (IAN) (Fig. 1), if present, pass almost entirely into the ether. Such ether-soluble root auxins have been separated chromatographically in a number of laboratories (Fig. 2 shows a typical analysis). The peak of auxin activity of the R_f of IAA seems to be due to natural IAA in the root. The peak at the R_f of IAN can be resolved into at least two compounds (neither being IAN) by further chromatography and the chemical nature of the α-accelerator and β-inhibitor zones is obscure.

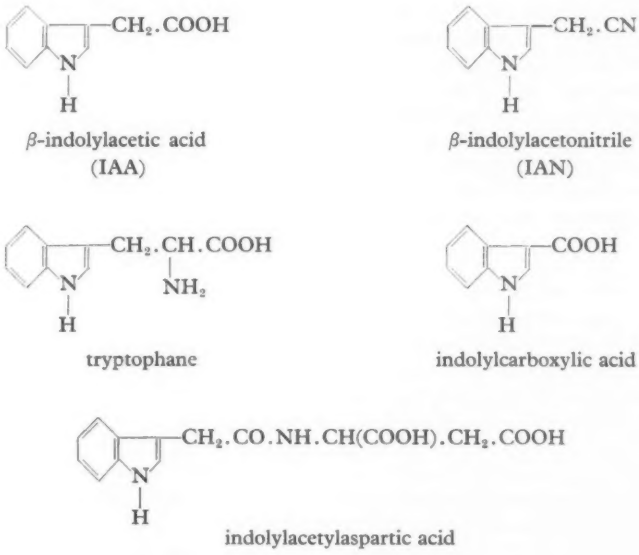

Fig. 1.—The structure of certain indole compounds.

However, when the aqueous root extract is exhaustively extracted with ethyl ether or ethyl acetate, as described above, the greater part of the auxin activity remains in the aqueous phase. Chromatography of such 'aqueous' fractions has yielded differing results not easily interpreted or reconciled. In our own laboratory, an interesting chromatographic separation of the auxin activity of this fraction of the root extract has been obtained with a low loading of the chromatogram. This activity is readily resolved into two zones of growth promotion (Fig. 3). The activity of Zone 1 is partly

due to its content of the indolic amino-acid, tryptophane (Fig. 1). This zone, however, also contains other growth-active material reacting with ninhydrin (a reagent giving coloured derivatives with amino compounds). Zone 2 is also rich in ninhydrin reactive material and can, on further chromatography, be resolved into at least four separate ninhydrin spots. The peak of activity follows one of these spots whose R_f in different solvents indicates that it is not one of the well known amino-acids of plant cells.

These chromatograms show that roots contain not one but a complex mixture of as yet chemically unidentified auxins, the most active of which are preferentially water-soluble. The individual roles of these auxins in the control of root growth has also yet to be determined. One important step towards this is currently being made by using, for the biological assay of chromatograms, a root growth test instead of the coleoptile straight-growth test hitherto used and which, of course, depends upon the control by auxins of the expansion of shoot cells.

The Metabolism of Absorbed Auxins

Chromatography combined with sterile root culture also makes possible studies of the metabolism within the root of auxins absorbed from the external culture solution. This approach has been opened up in our laboratory using physiological concentrations of IAA and IAN, the two natural auxins readily available as pure substances.

Chromatograms of the ethyl acetate fractions of cultured tomato roots show that feeding with IAA (10^{-6} g./ml. for 24 hr.) leads to a marked enhancement of auxin activity at the IAA position (R_f 0·55) (Fig. 4). Whereas chromatograms of this fraction from untreated roots give no colour reactions even with heavy loadings of extract, those from IAA-treated roots show four regions reacting purple with Ehrlich reagent (a reagent giving coloured derivatives with indoles and certain other classes of organic compounds). Two of these correspond with the growth-promoting zone centred at R_f 0·25. This zone, on further chromatography, can be shown to contain three compounds; indolylacetylaspartic acid (Fig. 1), a compound corresponding in R_f to indolylacetylglutamic acid, and an unidentified indole compound. When such IAA-treated roots are transferred to an auxin-free culture solution the activities at the IAA position and at R_f 0·25 rapidly decline suggesting the rapid metabolism of these growth-active compounds.

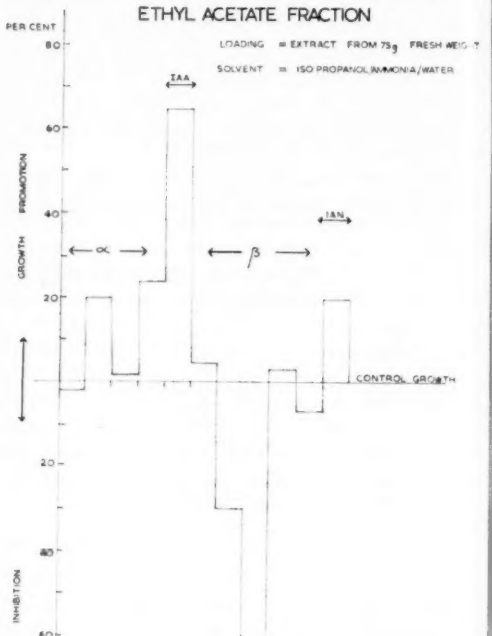

Fig. 2.—Chromatographic separation of the auxins soluble in ethyl acetate from 75 g. fresh weight of excised tomato roots. The results of the bioassay (coleoptile straight-growth test) represented by histograms of the growth promotions and inhibitions of the coleoptile segments as a percentage of their control growth in absence of the eluate from the chromatogram. The figure indicates the R_f values of IAA and IAN and the positions at which the α-accelerator and β-inhibitor zones (reported by other workers on chromatograms of the ether fraction of plant extracts) would be expected to occur. Data from Thurman (1960).

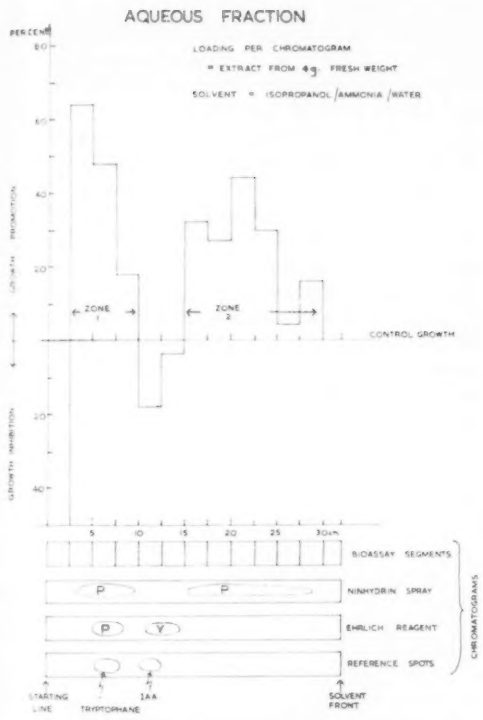

Fig. 3.—Chromatographic separation of the auxins preferentially soluble in water from 4 g. fresh weight of excised tomato roots. Bioassay results depicted as in Fig. 2. P = purple reaction in response to reagent. Y = yellow. The yellow Ehrlich reactor is urea. The purple spot with Enrlich reagent locates tryptophane. Data from Thurman (1960).

Feeding experiments with IAN (10^{-5} g./ml. for 24 hr.) gave high growth-promoting activity at the IAN position on chromatograms and also a spot corresponding in R_f and reaction with Ehrlich's reagent to indolylcarboxylic acid (Fig. 1).The very low activity of this latter compound in both coleoptile and root growth tests suggest that it does not account for the inhibiting effect of IAN on root growth. Both the accumulated IAN and indolylcarboxylic acid rapidly disappear on transfer of the roots to an auxin-free medium. The chromatograms yield no indication of any conversion of IAN to IAA. This confirms the conclusion, drawn from earlier studies (Street, McGregor and Sussex, 1954; Hughes and Street, 1960) of the influence of growth-inhibitory concentrations of IAA and IAN on cell division and cell extension in excised root cultures, that the activity of IAN is not due to its conversion to IAA.

The Control of Root Growth by Auxins

In the period since 1934 many papers have been published describing the effects on root growth of externally applied IAA and other substances with auxin activity. Many of these papers reported that auxin at very low concentrations was inactive and at higher concentrations always inhibitory to root growth; a situation which seemed each time to reinforce Cholodny's view that auxin functions only as an inhibitor of root growth. Work undertaken by the Swiss botanist, P. E. Pilet (1951, 1953), on seedling roots has, however, now shown that the response changes as the root grows; the growth of very young radicles being both more readily stimulated by low concentration and less readily inhibited by higher concentrations of external auxin than that of older roots. Such changes in response were correlated with evidence that the internal auxin level in the root rises naturally during growth, being initially below and later above the optimum for growth. Studies with isolated segments of seedling roots (devoid of the root tip, their source of auxin) have also shown that IAA at low concentration can markedly stimulate the growth of root cells (Audus, 1960). Similarly, work in our own laboratory has shown that the growth of the excised roots from a number of species is, under the appropriate cultural conditions, markedly enhanced by appropriate concentrations of auxins. Furthermore, when only inhibition can be obtained in response to auxin-feeding of root cultures then the growth of the cultures can always be stimulated by applying substances (anti-auxins) known to antagonise auxin action, suggesting that in such roots the cells contain an excess of natural auxin. These observations strongly point to auxin as an essential growth factor for roots, as conforming to Went's dictum 'no auxin, no growth'. The optimum auxin concentration for promotion of root growth is, however, clearly much lower than that for promotion of shoot growth and apparently, under natural conditions, the auxin level established in the root cells is often such that a further increase in its concentration by absorption from an external solution retards root growth.

The complexity of the auxin picture revealed by the chromatographic technique suggests, however, that IAA may only be one such compound involved in the control of root growth. Butcher (1960) has recently obtained convincing evidence that substances with the physiological activity of the gibberellins also occur in roots. Furthermore, substances related to the purine derivative, kinetin, shown to have dramatic effects on the growth and differentiation of plant tissue cultures, are universally present in plant cells. It is, therefore, of considerable interest that work involving the application of mixtures of auxins, gibberellic acid and kinetin to root cultures has shown that the rate of growth, the relative contributions of cell division, expansion and differentiation to growth, the form of the root system developed and so on are, under certain conditions, determined less by the concentration of any one of these growth factors than by the balance between them. Clearly, this complex situation cannot yet be interpreted in terms of the chemical events controlling the growth of root cells. It does, however, give us a qualitatively different picture from that of a single growth hormone as envisaged by the pioneer workers. Chromatography and sterile root culture seem, together, to have opened up exciting possibilities for further advances in our knowledge of the hormonal control of root growth.

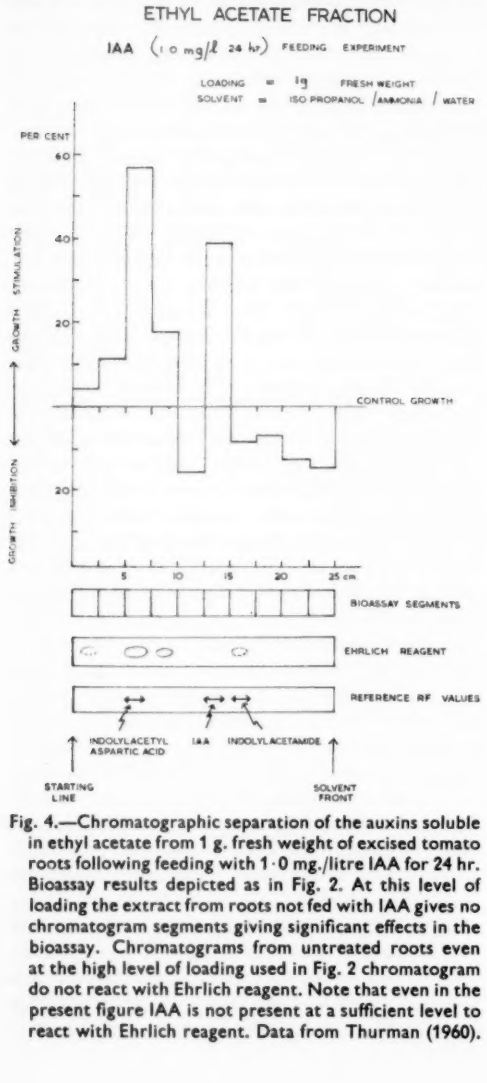

Fig. 4.—Chromatographic separation of the auxins soluble in ethyl acetate from 1 g. fresh weight of excised tomato roots following feeding with 1·0 mg./litre IAA for 24 hr. Bioassay results depicted as in Fig. 2. At this level of loading the extract from roots not fed with IAA gives no chromatogram segments giving significant effects in the bioassay. Chromatograms from untreated roots even at the high level of loading used in Fig. 2 chromatogram do not react with Ehrlich reagent. Note that even in the present figure IAA is not present at a sufficient level to react with Ehrlich reagent. Data from Thurman (1960).

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TECHNOLOGY AND PAKISTAN'S ATTACK ON POVERTY*

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In this address I would have liked to speak about the scientific field I have been privileged to work on, about the elementary particles of physics—those ultimate constituents of which all matter and all energy in the Universe is composed. I would have liked with you to explore the frontiers of our knowledge and our ignorance, to tell you of some of the concepts the physicist has created to comprehend God's design. I would have liked to show you that with all his pragmatism, the modern physicist possesses at once the attributes of a mystic as well as the sensitivity of an artist. I would have liked to convey to you some of the wonder, some of the fascination, as well as some of the heartbreaks of the physicist's craft.

But I shall not do this. In electing to speak on a general subject like 'Technology in relation to Pakistan's Attack on Poverty', rather than on elementary particle physics, I am following the illustrious tradition of my predecessors in this office. More particularly I have in mind the eloquent Presidential address on 'Technology and World Advancement' delivered by Prof. P. M. S. Blackett to the Dublin meeting of the British Association for Advancement of Science in 1957 (*see Adv. of Science*, **xiv**, 54, *Sept.* 1957). If I speak part of the time about the laws of economics rather than the laws of quantum physics, it is because like Blackett I interpret technology not in its narrow industrial sense but as something embracing the scientific organisation of most modern life. There are times when, in all humility, a mere scientist may also express himself on ideological matters, not because he has new insights to reveal but because there are things he believes passionately in, which need saying and can not be said often enough.

* Presidential Address delivered to the XIIIth All Pakistan Science Conference at Dacca on January 11, 1961.

We, in Pakistan, are very poor. This poverty we share with the majority of the human race, with some one thousand million people in about a hundred countries. Fifty per cent of us in Pakistan earn and live on less than eight annas a day; seventy-five per cent live on less than a rupee. This rupee a day includes the two daily meals, clothing, shelter and education if any. In contrast some four hundred million inhabitants of Europe and North America live on an average daily income of fifteen rupees.

It is important to realise that this uneven distribution of wealth is of relatively a recent origin. Three hundred and fifty years back Akbar's India and Shah Abbas's Iran compared favourably in living standards with Elizabeth's England. Soon after, however, the Western growth started. It coincided with a great technological advancement in agriculture and manufacturing methods. Now technical advances on a limited scale have occurred from time to time in the history of human societies. These advances have always led to increased prosperity. What, however, distinguished the nineteenth century technological revolution was the fact that it was firmly based on a scientific mastery of natural law. This gave man so much power, and it has led to so great an increase in production, that for the first time in human history, there is no physical reason for the existence of hunger and want for any part of the human race.

The realisation that hunger, ceaseless toil and early death can be eliminated for whole societies, and not merely for parts of societies is something new. The last hundred years have seen nation after nation, start with something like our conditions and crash through the poverty barrier. The laws governing this type of transformation are now well understood. First, a society must acquire the requisite technological skills; secondly it must save and re-invest more than 5 per cent of its national

income in productive enterprises. This minimum of 5 per cent just about offsets the depreciation of existing wealth. To double the standard of living in forty years needs an investment rate of 10–15 per cent; to double it in a decade, a nation needs to invest about 25 per cent of its national income.

Skills and capital—these then are the two prerequisites for building up a self-reinforcing economic growth. Nation after nation has achieved this in the last two centuries, each nation leaving the imprint of its own peculiar experience. Four of these experiences—those of Britain, Japan, Russia and China—however, stand out clearly. The British were the first to show that the poverty barrier can be crashed through if skills and capital are available. The Japanese showed that technology is communicable: that it is easy to learn and acquire. Having been conditioned for years to look with misty, uncomprehending eyes at the engineering miracle of an airliner, I still remember the shock of my life when I first visited the De Havilland aircraft factory at Hatfield. Instead of an organised assembly line where I expected to see molten aluminium being poured in at one and and a Comet airliner coming out at the other all I saw was something like an overgrown metal-smith's workshop in rural Pakistan. And when two women in overalls lifted a couple of aluminium sheets while a third started welding them together with a manually operated welder to make part of the fuselage, I am afraid I lost my respect for the mysteries of the manufacturing craft.

I do not for one moment wish to suggest that all technology is electrical welding. There is the other part of the story—the aerodynamic design of the Comet where the high-level scientific talent comes in. But the Japanese experience forced home the moral that technological competence is not a hereditary characteristic: that it can be acquired and in fact acquired rather quickly.

The third important lesson came from Russia. It showed that transition to sustained growth need not take a century or longer. It can be telescoped into the span of one man's life provided heavy industry receives top priorities. And then finally there is the Chinese experience underlining that cheap labour is itself a form of capital.

Summarising the economic part of our argument: skills and sufficient capital rightly invested are the major ingredients of self-reinforcing growth. On the road to achieving sustained, compounded growth of this type all nations have left the imprints of their peculiar experience, but four stand out: the British experience, showing that it can be done; the Japanese experience, that technology is easy to acquire; the Russian experience, that priorities on heavy industry accelerate the growth, and the Chinese experience that cheap labour is itself a form of capital.

The Situation in Pakistan

From this brief and highly idealised economic summary, let us turn to the realities of the situation in Pakistan.

The facts of our poverty are obvious enough and I am not going to mince words about it. You can go out in the streets and see it all around you. I am not referring now to the obviously shelterless, the obviously needy. I have in mind more the uncomplaining millions, with their suppressed hunger, the millions who, and I speak from experience, seldom get the two regular meals of the day; the millions who must often choose between buying badly needed food or a book for schooling their child. We live with a crushing poverty of the sort which Europe or America have not seen since the day when Dickens wrote. The marvel to my mind always is that the human spirit does not break and that most of the needy are still able to keep a dignified exterior.

The sense of what can be achieved, on the other hand, hits you most when you visit an affluent society like that of the United States. You just cannot believe the plenty—the plenty not for the few but for everyone. Everytime I am privileged to visit that great country, I have to remind myself afresh that it is indeed possible to produce so much for so many.

I do not say all this in any spirit of envy. This prosperity is due to an organisation of society where scientific knowledge is fully exploited to increase national productivity. This prosperity is a portent of hope: hope that possibly within our lifetime, using the same methods, we in Pakistan may also achieve the same.

Our poverty raises not merely material but also spiritual issues. The Holy Prophet, may peace and blessings of Allah be upon Him, said 'It is near that poverty may become synonymous with *Kufr*.'

'*Yukadu un yakun al-fagr-u kufr*'. I shall not attempt to translate *Kufr* into English: the nearest equivalents, apostacy or unbelief, can never convey the connotations which *Kufr* has for a Muslim audience. Let me say with all the vehemence at my command that I would like to see this saying of the Prophet on the doorpiece of every religious seminary in Pakistan. There may be other criteria of *Kufr* as well, but in the conditions of the twentieth century, in my opinion the most relevant criterion of *Kufr* is the passive toleration of poverty without the national will to eradicate it.

I have mentioned technological skills and capital as the two pre-requisites before a pre-industrial society like ours can crash through the poverty barrier. Actually there is a third and even more important pre-requisite. And that is the *National Resolve* to do so. In Prof. Rostow's words 'a nation's take-off into sustained growth awaits not only the build-up of social overhead capital—capital invested in communication net works, schools, technical institutes—it not only awaits a surge of technological development in agriculture and industry, but it also needs the emergence to political power of a group prepared to regard the modernisation of the economy as a serious high order political business'. Such was the case in Germany with the revolution of 1848, such was the case with Japan with the Meiji restoration of 1868; such was the case with the Russian and Chinese revolutions. Our independence in 1947 could have provided us with the necessary stimulus. Unhappily this was not the case. Our independence did not—definitely did not—coincide with the emergence of a political class which made economic growth the centre of state policy. I can still recall the interminable arguments, conducted in private and public, in the early years of Pakistan, about its ideology. Never in these discussions did I hear the mention of total eradication of poverty as one of the primary ideological functions of our new state.

True enough the country registered commendable progress in the manufacture of consumer goods—though, one must nor forget, with appalling suffering to the consumer himself. True enough the establishment of the Pakistan Industrial Development Corporation was a triumph. But at no time was this development purposefully designed to achieve the break-through we have talked about. The first five-year plan was commissioned in 1955, full eight years after independence. It did not receive formal approval of the Government till 1957. During these years there was a total neglect of the primary sector of our economy—agriculture; we squandered the windfall surpluses of the Korean war boom in buying, on open general licences, European cosmetics and radiograms. It is not that we failed to develop basic heavy industries. We did not even make any provisions for their future establishment; not even to the extent of starting to get our men trained in basic technologies. And, lastly, we completely neglected the exploitation of our minerals. Not even a survey was undertaken.

It would be right to date our progress to the 'take-off' from the assumption of power by the present Government. I believe when the future history of Pakistan is written the greatest significance of the revolution of 1958 will come to be recognised as the resolve for the first time of Pakistan's Government to achieve the break-through within five years. This resolve is reflected first by a recognition of the need for bold planning for agricultural development, for exploitation of minerals and most important of all, for heavy industry. Secondly, it is reflected in the recognition that a liberal provision for developing technological and scientific skills is the wisest investment a nation can make.

Take our new five-year plan first. It is a sagacious plan though perhaps not as audacious as I would like to see. It aims at achieving the crucial 10–15 per cent investment level. It places due emphasis on our primary sector of agriculture. It envisages the beginning of a basic heavy industrial complex, particularly the steel industry. And, most important, it sets about exploiting our one industrial source material—the Sui and Sylhet gas—to set up a petro-chemical industry.

Quite often one hears abroad the rather sneering statement that underdeveloped countries look upon steel mills as national monuments. I personally confess to this complex and for very good economic reasons. Without a heavy industrial base nothing is possible in the long run. To take one pertinent example given by Prof. Mahalanobis—the great Indian statistician—let us consider the problems of providing 700,000 tons of extra grain needed for the five million annual increase of Indian

population. There are four ways of getting this extra grain; buy the grain; buy fertiliser to grow the grain; buy plant to make fertiliser or finally build heavy engineering capacity capable of making fertiliser plants. The cost of buying grain works out at £300 million pounds; the cost of buying fertiliser is one-third of this, and the cost of fertiliser plant about one-fourth. But the real saving comes if one sets up heavy manufacturing capacity to make fertiliser plants. The cost then is just some 10 million pounds. If the last alternative is chosen, one must however start planning some eight or ten years in advance of the season in which the fertiliser would be used.

It is gratifying that so far as fertilisers are concerned, our planners have chosen the third alternative. We are not planning to buy fertiliser but we shall make it in the country. Personally, of course, I would strongly favour Mahalanobis's last alternative—to set up the heavy manufacturing capacity within the country to make fertiliser machinery. The Second Five-Year Plan has made a beginning towards this by contemplating steel production of 400,000 tons. As steel producers and consumers it will put us in the same world class as the Republic of Chile and though I cannot say I feel satisfied with this, it is at least a beginning.

Capital Investment

Turning again to the question of 10–15 per cent capital investment needed for achieving the economic break-through, there is a vital 3 per cent of it which must be provided for in foreign exchange to buy foreign goods, foreign machinery and foreign know-how. It is this crucial 3–4 per cent which must come from the advanced countries either in the form of long-term loans or outright gifts. During 1957–8 over the world, some two and a half billion dollars were provided by U.S.A., U.K., U.S.S.R. and France as aid to underdeveloped countries. Let us make no bones about it; this gift entails sacrifices for ordinary people like ourselves in the donor countries. In the United States, stores always show prices without the Federal tax. The tax is added on at the counter so that one is highly conscious of the extra imposition by the time the purchase is completed. Thus shopping around whenever I have had to pay the ten cents of Federal tax, the thought that at least a quarter of a cent was going into foreign aid lightened the burden for me. It also gave me added respect and admiration for all those who constantly make this sacrifice.

The economists have estimated that in order that this aid brings its fullest impact, it must be stepped up from two to at least three billion dollars annually and kept at this level—with a guaranteed continuity—for a very long time to come. To get the scale right, it is perhaps worth mentioning that the Marshall aid to Europe just after World War II ran to about twice this figure, though of course the rapid recovery of Europe made its continuance unnecessary after three years.

As I said before, the aid is a gift and it necessarily entails sacrifices and there is very little we can offer in return—at least for a very long time. Whether it will or will not be forthcoming is in the end a moral and a spiritual question. I can only quote sages like Rostow who has spoken of 'the resources of spirit, will, and insight which the West needs, quite as much as steel and electric gadgets, to do the jobs which extend not only to missile arsenals and the further diffusion of welfare at home' but to the Five-Year Plans of the nations abroad. I can only quote Blackett when he speaks about 'the uneven division of wealth and comfort among the nations of mankind, which is the source of discord in the modern world, its major challenge, and unrelieved its moral doom'. I do not know if a future historian will find it ironic that in 1960's three billion dollars of aid were not easy to find while 60 billion dollars were annually spent stocking the world arsenals with atomic weapons, missiles and rockets. And I find it strange that during 1957–8 while underdeveloped countries received 2·4 billion dollars in aid, they lost 2 billion dollars in import capacity—in getting paid less for the commodities like jute and cotton which they sell and in paying more for the industrial goods which they buy. Paul Hoffman calls this a 'subsidy or contribution by the underdeveloped to the industrialised countries'—a subsidy which almost washed away the entire sums received in aid. And as a physicist, I find it the height of hypocrisy to pretend that the man-made satellites orbiting in space and each costing at least as much as the entire yearly budget of Pakistan have been sent up only to collect data on cosmic rays. All this makes no sense. It all points to one thing; the bankruptcy of world statesmanship in dealing with problems

of hunger and want. Dare I say what the world needs today is a great successor to Keynes to preach on a global scale that the raising of living standards of any depressed region is a collective world responsibility. Dare I say that we need a great successor to Roosevelt to give a New Deal not simply to one part of the United States but to a large part of the human family.

Education for Technology

I have talked so far about our plans and the position regarding capital. I now wish to turn to the question of the provision of technical skills. And this is where we as scientists directly come in.

Nowhere more than in this respect can we see the force of my remarks regarding the recent change of climate in Pakistan. This change is embodied particularly in the work of the Education and the Scientific Commissions.

Consider first the category of technicians who understand the scientific foundations of their craft. It is an awful fact but nevertheless true that in the entire liberal arts-dominated educational history of British India, there never was anything analogous to the British National or Higher National Certificates in Technology. I could not believe it when I was first told that Great Britain has 300 colleges of technology spread all over the country training 30,000 technicians every year. One of the most far-reaching recommendations of the Education Commission is the provision to establish enough technical schools and polytechnics to produce 7000 technicians a year. Our major problem is the staffing of these technical institutions. I purred with pride last year when Sir John Cockcroft spoke to me about the excellence of our army technical schools and their technical instructors. I am sure it will not be impossible to tap this reservoir for providing teachers in the early stages.

We in Pakistan are disposed to think of Scotland as a prosperous state within the British Commonwealth. I was startled the other day to read an article by Dr. J. M. A. Lenihan, entitled 'What is wrong with Scotland?' After painting a rather gloomy picture of consistent economic decline Dr. Lenihan concludes that this decline stems entirely from lack of trained technologists. To the objection that if there is no industry in Scotland, there is no need for technical colleges. Dr. Lenihan counters by remarking 'The scientist, the technologist and the technician are, in the main products of the educational system, not of the industrial system in which they hope to work. A coherent demand for technical education facilities will not rise from an assortment of industries but the existence of technically trained people will facilitate the growth of new industries.'

Dr. Lenihan's view point about skills coming before industrialisation has of course a peculiar relevance to our situation in Pakistan. Some ten days back I heard a similar comment from Prof. S. Tomonaga, the great Japanese physicist, now President of Tokyo University. Speaking of the spectacular rise of the Japanese transistor industry, Prof. Tomonaga attributed it to a careful cultivation of the art of calligraphy. Every Japanese child must spend years learning the calligraphic arts at school; this develops a sensitivity of touch, a nimbleness of fingers, peculiarly suited as they have now discovered to transistor assembly and development. Clearly no skills or special talents a nation may cultivate are ever wasted when the spark of industrialisation comes along.

There is one other passage from Lenihan's address which I would like to quote. After listing a number of difficulties which face Scottish economy he goes on to say 'Many of the difficulties that have been mentioned are the natural consequences of living in a country'—that is Scotland —'where science is not taken seriously enough. How else can we describe a country which, fighting for economic survival in a world dominated by technology, allows the basic sciences of physics and chemistry only the status of half subjects in the school curriculum.' There is perhaps, in Dr. Lenihan's remarks, a considerable moral for Pakistan's secondary education.

Perhaps the most depressed community, till recently, among technicians in Pakistan was—and so far as University teachers are concerned still is —the community of scientific workers. All scientific research institutes in Pakistan have been run under the uncomprehending bureaucratic control of Government ministries. And when I say control, I mean control. We seem never to have recognised that in a science-dominated world, there ever could be any tasks for the Pakistani scientists. The official attitude towards Science was at best been one of reluctant indulgence; somewhat like the attitude of the learned divines in the worst and most in-

tolerant days of the Bukhara Emirate towards the local clock-maker who was a Christian. He was permitted to enter the mosque for repairing the tower clock only on the plea that after-all in the matter of technical usefulness he was on par with the donkeys which carried the stone-slabs into the mosque in the first place. Why should the clock-maker suffer a greater social disability? Not only did our bureaucracy adopt the divines' attitude to the clock-maker but also if possible the clock-maker was hired from abroad

One aspect of this neglect is the awful fact that there are so few of us in the country. According to the statistics collected by the Scientific Commission there is a total of sixty trained physicists in Pakistan. To get the scale right, this is roughly the number of correspondingly trained men you may find in any one London College. In scientific research, unfortunately, it is no longer possible for a single person to achieve his individual break-through. Before science can flourish and a scientific tradition can develop, there has to be a critical size, a critical number of trained scientists at one place. Once the critical number is reached, the chain reaction starts; the group becomes self-reacting. Otherwise it simply withers and dies away.

I have great hopes that all this is going to change. As you know a Scientific Commission was appointed by the Government last year, and it has presented its report. From the manner the Government have reacted to reports of its previous Commissions, I venture to predict that 1961 may be the beginning of a new era for scientific research in respect of its organisation, in respect of the massive training programmes which may be initiated and in respect of the calls which the nation may make on its scientific talent. In fact a feeling that the boot may soon be on the other foot. I only hope we, as scientists, can rise to the challenge and are not found wanting and unprepared.

What exactly are the tasks where we as scientists can make an immediate contribution? One could list a number, ranging from problems of low-productivity in agriculture, problems of flood control and water logging, to the optimum use of Sui-gas. To take one concrete example a new method for gas-reduction of low grade iron ore has been developed in Mexico. Most steel producing countries are of course not interested in gas-reduction for they possess plentiful supplies of coke. The Mexican process is producing one million tons of steel annually. Our situation in Pakistan is similar to that of Mexico. We possess gas as well as low-grade iron ore. It is gratifying that our Department of Scientific and Industrial Research has independently started a small development project, for the process. If successful, it may revolutionise our steel economy. Would you not agree that the project needs top-most blessing and the highest priorities?

I would like to end by briefly reiterating some of my remarks. In hoping to achieve the break-through to national prosperity, we like most other poor countries depend considerably on numerous factors beyond our national control. But there are a number of internal pre-requisites the nation must satisfy before the transformation of our society will take place. The first and foremost of these is the firing of the entire nation and harnessing of its spiritual energy, to the objective of eradication of poverty within one generation. This will need constant reiteration of the economic objectives; in particular this will need convincing the nation that the economic policies are designed to enrich the whole society and not merely a part of it. I do not know how the youth of Dacca spend their evenings but as a measure of the nation's consciousness, I shall feel happy when Lahore, for example, makes a transition from its present literary to a technological culture and instead of love-lyrics in the Mall cafés the discussions range freely and fiercely—at least part of the time—over the targets of the Five-Year Plan.

Let us be absolutely clear about the nature of the revolution we are trying to usher in. It is a technological and scientific revolution and thus it is imperative that topmost priorities are given to the massive development of the nation's scientific and technological skills. And finally let us as scientists face and live up to the challenge thrown up by Pakistan's poverty. Let future historians record that the fifth important lesson in economic transition to prosperity was taught by Pakistan in achieving a rate of growth as rapid as the Russian and the Chinese but without the corresponding cost in human suffering.

Let me end by quoting from the Holy Quran.

The Lord changeth not what is with a people
until the people change what is in themselves.

THE COMMERCIAL PRODUCTION OF SILICONES

By Dr. R. A. GREGORY *Managing Director, Midland Silicones Ltd.*

Commercial production of silicones first began at the Corning Glass Works in the United States in 1942. A year later Dow Corning Corporation was formed and a plant was erected in Midland, Michigan, to make a variety of organosilicon products demanded by the military forces. The first major silicone product was a grease for coating the sparking plugs of aircraft engines. The General Electric Company of America was also active in silicone research and small-scale production in the early nineteen-forties. After the end of the war the two American producers had to find new non-military uses for their products and establish a market for the early types of silicone fluids, greases, rubbers and resins. A few years later manufacturing activities were started up outside of the United States and there are now two major producers in the United Kingdom, two in France, three in Western Germany and two in Japan, as well as three in the United States. There are also believed to be several operating factories in Russia and one in East Germany. Very few production statistics are released but by piecing together what evidence is available it seems probable that the total world production of silicones is now around 20,000 tons of finished products as sold, that is to say, including solvents and other diluents where these are used. About two-thirds of this total, say 10,000 to 15,000 tons, is produced in the United States, probably between 2000 and 4000 tons is produced in Russia and East Germany and between 1000 and 2000 tons each in the United Kingdom, France, Germany and Japan.

The more important manufacturers each make a range of some 100 or 200 different products. The average world selling price is around 20*s*. per pound, but there are wide variations from this mean. For example, some textile treating emulsions sell for a few shillings a pound whereas some special fluids and rubbers cost several pounds sterling a pound. However, taking the average figures for world production and selling price the value of the world output of silicones is now of the order of forty or fifty million pounds sterling.

It is as well to define what is commonly meant by the term 'silicone'. The term tends to be widened by common usage to include almost any organosilicon compound used and produced commercially although the use of the term more properly should be restricted to mean silicon polymers containing silicon–oxygen–silicon bonds and also containing a significant proportion of hydrocarbon radical groups directly attached to the silicon atoms. Some of the newer carbon-functional silicones and silicone-modified organic resins contain quite a minor proportion of siloxane bonds.

For the first few years most commercial silicones contained only methyl or mixtures of methyl and phenyl as the hydrocarbon radical groups attached to the silicon atoms but polymers containing minor proportions of vinyl groups have now become common. Products containing SiH bonds in addition to silicon–hydrocarbon radical bonds were also introduced at an early stage. More recently special products have been introduced containing such groups as ethyl, fluoroalkyl, chlorophenyl, nitrile, carbonyl, amino and hydroxyl attached to silicon.

The method universally employed for the manufacture of silicones is by hydrolysis of organic substituted chlorosilanes which are produced as intermediates.

The simplest chlorosilane is silicon tetrachloride and by replacing one, two or three chlorine atoms by hydrocarbon radical groups silicon carbon bonds

are formed which are stable to hydrolysis. Any remaining SiCl bonds not replaced by silicon hydrocarbon bonds in this way are readily hydrolysed by water giving, first, an SiOH bond, which will usually react readily with another such bond, giving an Si—O—Si or siloxane link by the elimination of a molecule of water.

Silicones containing only methyl groups as the organic substituent are the basis of the most widely used type of commercial silicone product, namely the silicone fluids. The methyl groups confer the valuable properties of small viscosity change with temperature, high compressibility and good stability at high temperatures as well as the general properties of water repellency and physical and chemical inertness common to other silicones. When some of the methyl groups are replaced by hydrogen atoms the silicone shows even less change of viscosity with temperature but loses some of its heat stability. This latter property is utilised commercially, for the methyl hydrogen siloxane polymers are used for treating textiles, the unstable SiH bonds being a means of curing the silicone on to heat sensitive materials. When ethyl or phenyl groups are substituted for some of the methyl groups, the change of viscosity with temperature increases but with phenyl groups other properties such as lubricity and oxidative stability may be improved. Silicone fluids containing a substantial proportion of phenyl groups are important as diffusion pump fluids, heating fluids and as components of high temperature lubricants. Mixed phenyl methyl polymers are also the basis of most commercial silicone resins. Substitution of a few methyl groups in a polymer by vinyl groups gives silicone rubber gums with better curing characteristics than all methyl gums, while substitution of methyl by fluoroalkyl or cyanoalkyl groups gives polymers which swell less when immersed in aromatic solvents or carbon tetrachloride.

The methyl chlorosilanes, from which the methyl silicones are derived, are manufactured by the 'direct process' first discovered and patented by Rochow in the United States. A pilot plant using this process was in use at the General Electric Research Laboratory in America in 1941. The process was independently discovered by Müller in Germany during the war and described in a secret war-time patent. The direct process, which, as its name suggests, has the virtue of simplicity, produces chlorosilanes in a single stage from metallic silicon and it soon displaced the Grignard process developed by the Dow Chemical Company as the major commercial route to silicone intermediates. Stated in general terms it is a process in which an organic halide is reacted directly with silicon metal in the presence of a metallic catalyst which is generally copper, but by far the best yields are obtained when the halide is methyl chloride. The temperature of reaction for silicon and methyl chloride is about 275–300° C. and the simple equation to represent the reaction would be $2CH_3Cl + Si = (CH_3)_2SiCl_2$ but in practice some thermal degradation and molecular rearrangement takes place so that one always obtains a mixture of mono-, di- and trimethyl substituted chlorosilanes together with small quantities of a wide variety of other by-products. The reaction is exothermic (the heat of formation of $(CH_3)_2SiCl_2$ from CH_3Cl is about 80 kilocalories per gram mol) and presents all the usual chemical engineering difficulties of reacting a gas efficiently with a solid. Various designs of reactor are employed, the object being to obtain as good contact as possible between the gas and the finely divided solid, and to remove the heat of reaction as fast as it is formed. The development of local hot spots must be avoided as much as possible in order to minimise the formation of thermal degradation products. One type of reactor consists of a horizontal rotating tube which is partly filled with powdered silicon together with a small proportion of added copper. The silicon is readily available commercially in a 97–99 per cent pure state. The reactor may be from 2 to 6 ft. in diameter and 40 to 60 ft. long. It is usually fitted with lifting flights to increase the gas-solid contact or a stationary reactor may be used with a rotating stirrer. The tube is jacketed and thus may be externally heated or cooled, either with air or with a heat transfer fluid. Superheated methyl chloride vapour is fed in at one end of the previously heated reactor which is frequently operated at a few pounds pressure. When reaction commences, cooling is applied to the reactor jacket so as to maintain a steady temperature of about 275–300° C. The product leaving the far end of the reactor, which consists of mixed methyl chlorosilane vapours and excess unreacted methyl chloride is cooled in tubular condensers, the first

of which is water cooled and the second is cooled with refrigerated brine. These condense out the methyl chlorosilanes (boiling points between 30 and 70° C.). The vapours leaving the second condenser are then compressed to 100 p.s.i. and cooled again to recover the unreacted methyl chloride together with a further small amount of chlorosilanes. This mixture is fed to a continuous still operated under pressure and the recovered methyl chloride is recirculated through the reactor. The so long as precautions are taken to prevent the intake of moisture anywhere in the system.

The direct process is also used for the production of phenyl chlorosilanes although on a much smaller scale. Chlorobenzene is reacted with a silicon–copper mixture at around 500° C. but the yield of desirable products (mainly mono phenyl trichlorosilane) is not as good as with the methyl chloride reaction. Addition of hydrogen chloride gas assists in the reaction.

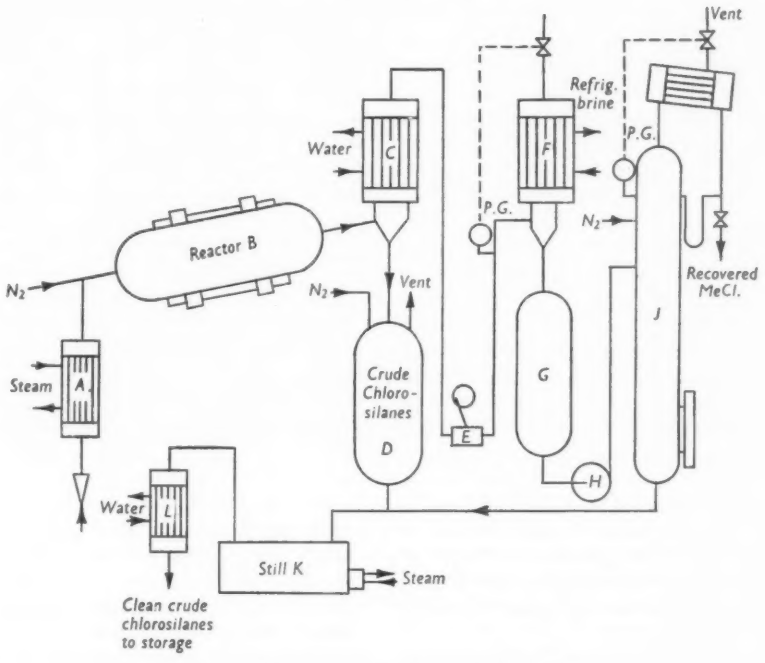


Fig. 1—Plant for direct process for methyl chlorosilanes.

general arrangement is shown in the flow diagram. The silicon bed in the reactor is renewed from time to time. (Fig. 1.)

A second type of reactor consists of a vertical tube which may be fitted with some type of stirring gear or operated as a fluid bed. A typical reactor is 2 to 3 ft. in diameter and 15 to 20 ft. high. The tube is jacketed for external heating and cooling and the same type of condensing system is provided as for the horizontal type reactor. The whole equipment may be constructed in mild steel

Silicon metal will also react directly with hydrogen chloride alone at about 300° C. The product is mainly trichlorosilane, $HSiCl_3$, and equipment similar to that used for the methyl chloride reaction is used for this process. Trichlorosilane, apart from being a useful intermediate for the production of transistor grade silicon of extremely high purity, also provides a useful route to chlorosilanes which cannot be manufactured in good yield by the direct process method. This use of trichlorosilane involves the general property of a silicon hydrogen

bond to add on directly to an olefinic or acetylenic compound at the unsaturated bond. Thus ethylene and trichlorosilane when reacted together under the right conditions will give ethyl trichlorosilane, acetylene and trichlorosilane will give vinyl trichlorosilane, and acrylonitrile and trichlorosilane will give cyanoethyl trichlorosilane. These reactions are catalysed by ultra violet light, platinum and by organic peroxides and bases, or they may be run at higher temperatures and pressures without catalysts.

Two other reactions of trichlorosilane used commercially are, first, heating with a halogenated aromatic hydrocarbon such as chlorobenzene to give, for example, phenyl trichlorosilane and hydrogen chloride. Secondly, the reaction of an aromatic hydrocarbon and trichlorosilane in the presence of boron trichloride as a catalyst to give an aromatic trichlorosilane and hydrogen. These reactions are carried out under pressure and at about 250° C. in a mild steel autoclave. The first reaction can also be applied to vinyl chloride to give vinyl trichlorosilane. The second method gives a useful alternative route to phenyl trichlorosilane. This property of the SiH group can also be employed in a similar manner with the compound methyl hydrogen dichlorosilane CH_3HSiCl_2. This material is obtained as a by-product in the direct process reaction between silicon and methyl chloride and apart from its importance as an intermediate for making silicone fluids for treating textiles, the SiH bond gives a ready method of synthesising mixed radical disubstituted dichlorosilanes such as methyl vinyl dichlorosilane, methyl ethyl dichlorosilane and methyl phenyl dichlorosilane.

Two other methods of making chlorosilanes should be mentioned. The first of these is the Grignard process for replacing a chlorine atom attached to silicon by an organic group, by reacting the chlorosilane with the required magnesium metal organic halide complex. Originally an essential part of silicone manufacture, this process has now been largely superseded by the direct process but it still provides a useful method for making some of the less commonly used chlorosilanes. The usage of magnesium, which is converted to magnesium chloride of no commercial value, and the substantial volumes of ether and toluene required as solvents make it an expensive operation commercially. The first stage in the process is to prepare the Grignard compound, say phenyl magnesium chloride, by heating and stirring chlorobenzene and magnesium turnings under pressure in the presence of ethyl ether. Once the reaction has started, cooling has to be applied to the reactor. The ethereal solution of the Grignard compound is then carefully added, with efficient stirring, to a toluene solution of a chlorosilane, sufficient being added to replace one or more of the chlorine atoms in the chlorosilane with a phenyl group. The product is pumped through a totally enclosed type of filter press to separate off the magnesium chloride precipitate and fractionally distilled to recover the solvents and purify the product. The second of these lesser used industrial processes is the so-called rearrangement process whereby, in the presence of aluminium chloride as catalyst, atoms and radicals attached to silicon will shift from one silicon atom to another. As an example of this, if a mixture of monomethyl trichlorosilane and trimethyl monochlorosilane is heated under pressure at about 350° C. together with a little aluminium chloride, a useful yield of dimethyldichlorosilane is obtained. This process is useful for reworking surplus by-products obtained in any of the foregoing processes.

Each of the commercial methods described above will give a mixture of compounds which have to be separated to a high degree of purity before they are suitable for further use. Fortunately the commonly used chlorosilanes are all mobile liquids with boiling points ranging from 30° C. to 300° C. so that separation by fractional distillation is the industrial method of choice. Some separations are difficult because of the close proximity of the boiling points of the components of a mixture, for example, the three methyl chlorosilanes boil within a range of thirteen degrees, and high efficiency distillation columns are required. Some of the lower boiling constituents are distilled under pressure while the higher boiling phenyl-containing chlorosilanes are distilled under vacuum. So long as moisture is rigorously excluded there is no particular difficulty with the materials of plant construction and mild steel columns with bubble cap trays, sieve plates or packed with raschig rings are commonly used. Since the various types of crudes produced by the processes previously described generally contain from five to

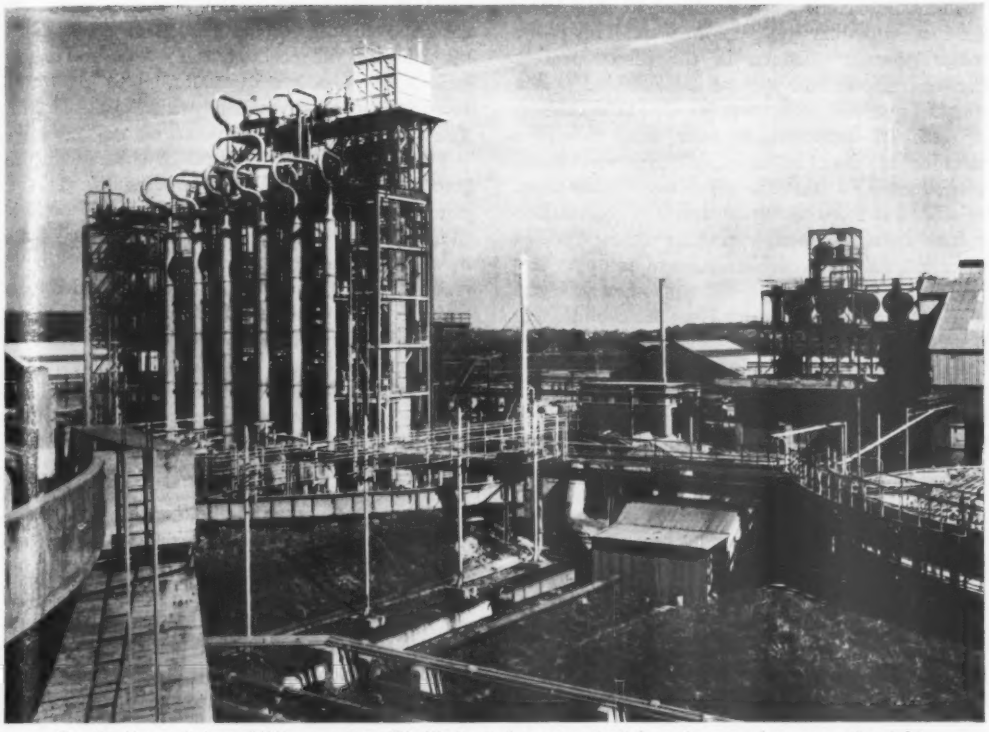


Fig. 2—General view of Silicones plant. Distillation columns on the left, resins manufacture on the right.

eight components, a train of three or four continuous columns is normally used to effect the separation and a further batch distillation of some of the fractions may be required to meet the high purity specifications. Some of the columns require between 100 and 200 theoretical plates and the plant needs to be well provided with instruments so as to maintain steady operating conditions. Infra-red spectroscopy and vapour phase chromatography are used as control tests to ensure that the high standards of purity are maintained. There is a considerable fire and explosion hazard in handling chlorosilanes and an internal atmosphere of dry nitrogen is commonly used throughout the plant. (Fig. 2.)

After separating the intermediate chlorosilanes by distillation into pure components the next stage in manufacture is to synthesise from them a variety of siloxane polymers. This is done by reacting carefully prepared mixtures of chlorosilanes with water and thus replacing all the SiCl bonds in the chlorosilanes by SiOH and Si—O—Si bonds. Practically all commercial silicone products with the exception of the resins are based on long-chain siloxane polymers. To build up the long Si—O—Si chains, chlorosilanes with two chlorine atoms attached to each silicon atom are required so that on hydrolysis each silicon is bonded to two oxygen atoms, the remaining two valencies being occupied by methyl or phenyl. To limit the length of the polymer chains some end-blocking groups are introduced. These have only one SiO bond and are derived from mono-functional chlorosilanes such as trimethyl chlorosilane. Silicone resins, however, have a three-dimensional siloxane structure and to achieve this some components containing three chlorine atoms attached to each silicon atom are required.

The chlorosilane most widely used in silicone production is dimethyl dichlorosilane. This is the major product obtained in the direct process between silicon and methyl chloride and it is a mobile liquid of boiling point 70° C. The hydrolysis of dimethyl dichlorosilane with water to give a mixture of dimethyl siloxanes is conveniently carried out as a continuous process in glass-lined or other acid resisting equipment. The chlorosilane reacts very readily with cold water which, if added in excess, results in the formation of an upper oily layer of siloxane and a lower aqueous acid layer. The reaction is accompanied by the evolution of heat. The dimethyl dichlorosilane and water are fed by means of metering pumps into a small glass lined mixing vessel the proportion of water being adjusted so that all the HCl produced is recovered in the aqueous layer as concentrated hydrochloric acid. The contents of the mixing vessel are continuously circulated through a cooler to remove the heat of reaction. Some of the circulating mixture is drawn off continuously into a separation chamber where it divides into two layers. The top siloxane layer is run off and washed with water until it is free from acid. The dimethyl silanediol $(CH_3)_2Si(OH)_2$ formed as the initial product condenses very readily with the elimination of water to give a mixture of cyclic polymers $((CH_3)_2SiO)_x$ where x is mainly 4 and hydroxyl end-blocked linear polymers of general structure

$$HOSi(CH_3)_2(OSi(CH_3)_2)_yOSi(CH_3)_2OH$$

The subsequent processing of this crude product depends on its end use. For the preparation of elastomers and high viscosity fluids it is fractionally distilled to give a pure fraction of cyclic polymers. The residue left after this distillation together with undistilled material is suitable for the preparation of medium and low viscosity fluids. These are made by condensing the short chain silanols and cyclic polymers into long-chain polymers in the presence of either sulphuric acid or potassium hydroxide as catalyst. To control the length of the long-chain polymers some hexamethyldisiloxane $(CH_3)_3SiOSi(CH_3)_3$, obtained by hydrolysis of trimethyl chlorosilane, is added as end blocker. The mixture is heated in a stirred stainless steel or glass lined vessel (depending on the catalyst used) under reflux at 130–160° C. Equilibrium is reached in a few hours. The equilibrium mixture still contains some low molecular weight polymers and these are removed, after neutralization of the catalyst, by stripping the product at 250° C. and a few millimetres absolute pressure. The recovered volatiles can be polymerised with the next batch. The stripped product is filtered before sale.

The hydrolysis of mixtures of chlorosilanes to give resin hydrolysates is a much more difficult process than that just described. This is because the three-dimensional hydrolysates formed from mixtures of di- and tri-functional chlorosilanes are much more reactive than dimethyl hydrolysate and reaction conditions such as time, temperature and acid concentration must be carefully controlled in order to obtain reproducible results. The chlorosilane mixture is often diluted with solvent such as toluene or xylene before reacting it with water so as to give better reaction control. A typical mixture of chlorosilanes for the manufacture of a silicone paint resin or electrical insulating varnish would contain mono and dimethyl chlorosilanes and either mono or diphenyl chlorosilane. To hydrolyse such a mixture a glass-lined kettle fitted with an agitator is partly filled with toluene and then two separate streams, one of mixed chlorosilanes in carefully measured proportions and the other of water, are run into the vessel beneath the surface of the solvent. The hydrolysis reaction is endothermic but the heat of solution of hydrochloric gas in water gives overall a considerable evolution of heat. By restricting the amount of water added the reaction temperature can be maintained approximately constant and the HCl is recovered partly as gas and partly as saturated aqueous acid. The siloxane produced dissolves in the solvent layer and when all of the reaction mixture has been added the solvent layer is run off and washed with water until free from acid. Troublesome emulsions may form at this washing stage. The crude hydrolysate thus formed may contain several per cent by weight of hydroxyl groups and some of these have to be removed by polymerising the siloxane further in order to produce a resin of workable viscosity and reasonable time of cure. This polymerisation or 'bodying' as it is frequently called, is achieved by heating the solvent siloxane solution for several hours at 110–130° C. either alone or in the presence of a catalyst such as zinc octoate. The major part of the solvent distils off in the process and carries off with

it azeotropically the water produced by condensation of some of the hydroxyl groups on the siloxane. When the desired viscosity and cure time has been reached the resin is rapidly cooled by adding cold solvent to give the desired siloxane concentration for sale (frequently 50 or 60 per cent by weight). This stage of the process is usually carried out in stainless steel equipment mainly on grounds of cleanliness and to prevent contamination with iron salts. The product is finally clarified and filtered and curing catalysts may be added as required.

Similar care in the hydrolysis procedure is necessary in making the special fluids used for treating textiles to render them water repellent. These fluids are made by hydrolysis of methyl hydrogen dichlorosilane CH_3HSiCl_2 with the addition of a little trimethylchlorosilane as end blocker. The SiH bonds in the long-chain siloxane polymer thus produced, react readily, especially in the presence of catalysts, to give cross-linked polymers and free hydrogen and as previously mentioned this reaction is used as a means of curing the siloxane on to cloth at temperatures which do not harm the fabric. The hydrolysis procedure must be carried out with efficient mixing and temperature control otherwise some of the SiH bonds are destroyed in the process and insoluble gels will result.

Silicone rubbers are made from silicone gums by the addition of fillers and catalysts. The simplest gums are made by heating and stirring a refined grade of dimethyl siloxane with a trace of alkali or ferric chloride catalyst. The siloxane, prepared as previously described by distillation of crude dimethyl hydrolysate, must be exceptionally free from tri functional materials otherwise cross-linked polymers are produced which will not give good rubbers. The polymerisation is usually carried out batchwise at 150–200° C. and the product is a clear water white fluid which flows while hot but sets to a very viscous gum when cold. Most modern silicone rubbers contain small amounts of organic groups other than methyl attached to the silicon atoms. The addition of several per cent by weight of phenyl polysiloxanes give improved flexibility to the rubber at low temperatures. The addition of a fraction of a per cent of vinyl siloxane gives improved curing properties to the polymer. These additions are made by co-polymerising the required proportion of diphenyl siloxane or vinyl methyl siloxane with the dimethyl siloxane. The high strength silicone rubbers contain very finely divided silica as filler. Heat stability of the rubbers can be improved by adding iron compounds; compression set may be improved by adding mercury compounds or cadmium compounds, usually the oxides or carbonates. Zinc oxide and titanium oxide are also used as general purpose fillers. In making the compounded rubbers the gum and fillers are initially mixed in a dough mixer. The mixture is then transferred to a two roll rubber mill or three-roll paste mill depending on its consistency. Further additions of filler may be made on the mill and the vulcanising agent—usually an organic peroxide—is also added on the mill. The batch is milled and cross-blended until it is completely uniform and then strained through a fine wire gauze to remove any particles of dirt that may have been picked up in the process or derived from the fillers. The products as sold vary in consistency from pourable creams to heavy plastic clays and only develop their rubbery properties after heating to promote cross-linking by the action of the organic peroxides.

The silicone bearing greases and other grease-like materials including antifoaming compounds are made in a similar way to the more fluid type of silicone rubber compounds in which a high viscosity fluid polymer is used instead of a gum. A blend of silicone fluids, depending on the properties required in the end product, is mixed with finely divided fillers such as silica, metallic soaps or graphite in any simple form of mixer. The product is then milled until uniform on a standard three-roll paint or grease mill, filtered through a fine wire gauze and packed in drums, jars or tubes.

Finally, brief mention should be made of the carbon-functional silicones which at the present time account for only a small fraction of total silicone sales. These are silicones in which one or more of the stable hydrocarbon groups attached to each silicon atom has been replaced by a reactive organic group. Typical examples of reactive organic groups attached to silicon are vinyl, chloroalkyl, cyanoalkyl, hydroxyalkyl and amino-alkyl, and we may also include in this definition, silicon-containing aldehydes, ketones, carboxylic acids and esters. There is a great mass of chemical knowledge in this field which is largely still con-

fined to the laboratory but there have been some commercial developments also. The importance of vinyl-containing siloxanes has already been mentioned and reference has been made to the fact that rubbers containing fluoroalkyl or cyanoalkyl siloxanes show improved solvent resistance. Methyl and phenyl groups attached to silicon may readily be chlorinated or brominated. The resulting materials are largely used as laboratory intermediates for further syntheses although chlorinated phenylsiloxanes are used as components of high temperature lubricants. Amino alkyl silicon compounds are made by reacting chloroalkyl silicon compounds with anhydrous ammonia or amines. They have found use in conjunction with organic resins in the production of glass fibre laminates. Silicones containing unreacted silanol groups or alkoxy groups may be co-polymerised with alkyd, epoxy and phenolic resins giving paint resins and varnishes. These materials lack some of the high temperature resistance of ordinary silicones but have improved flexibility and show promise as surface coatings.

With the large amount of research work now in progress throughout the world on organo silicon chemistry the future should bring not only new silicones and related polymers but also new methods of making the present silicone products and a vigorous expansion of the silicone market for many years to come may be confidently predicted.

EDUCATION AND TECHNOLOGICAL CHANGE

By **Prof. J. W. TIBBLE** *Department of Education, University of Leicester*

The aim of this paper is to call attention to some of the characteristics of those societies in which technological processes have been most fully developed and to consider the implications for education. Perhaps the most important of these characteristics, for our purpose, is the marked acceleration in the rate of change from one generation to the next. Changes occur in all the societies that we know about but in primitive societies and even in the great civilisations of the past, the rate of social change was relatively slow; in general the skills and attitudes a child needed when grown up would not differ much from those of his father and grandfather. This is clearly no longer so in the developed societies of our time, or indeed in less developed societies which have been affected by western civilisation. As is pointed out in the Crowther Report, a young person entering employment today may spend a large part of his or her working life in a job which does not yet exist, concerned with processes not yet invented and using machines still to be designed. And this is true not only of 'modern' industries but of agriculture, printing, transport and the retail and distributive trades. It is also true, in varying degrees, of leisure time occupations and of social habits and attitudes. Underlying this acceleration in the rate of change is a modification in our attitude to the factor of change itself. This is seen as something inherent in the nature of the universe, as we understand it in the light of developments in physical and biological sciences. It is a dynamic not a static universe and the understanding and possible control of the changes going on in it has become a major preoccupation of modern societies.

This has some profound implications for education. The traditional function of education in all societies has been conservative, to preserve and hand on to the next generation the skills, knowledge, beliefs and attitudes valued by that society. This function derives from the biological nature of man, who is born helpless, ignorant and dependent and having to learn from others in early life most of the things he will need to function adequately as an adult—or indeed as a child—in his society. This applies to our society too, of course, but we have to incorporate in what is handed on the preparation for change and the capacity to go on acquiring new skills and attitudes throughout life, including some which cannot be precisely forecast by the present adult generation. Nor is it a question of simply adding on something new to the old. For the new often involves a modification of existing traditions, techniques and customs. We have therefore to include in our function as educators the revaluation of tradition in each generation, the selection of what is still valid and what may need modification; and we have to train our pupils to make this kind of assessment for themselves. This means that in general the inculcation of specific skills and knowledge becomes less important than formerly and the development of flexibility, capacity for adjustment, and the understanding of principles and processes becomes more important. But this is to oversimplify the relation between specific and general—we need to re-define and relate these terms in the context of a dynamic society. As Drucker has said, 'The educated person today needs to be generally educated; he must also be a high grade specialist, and he needs a general education most in the area of his speciality. He needs the humanities and the sciences—but he needs a systematic discipline in the humanities and a humanist approach to the sciences, an understanding of their philosophical foundations, their logic, their values. He needs

systematic knowledge which only systematic learning can give. But he needs also very high ability to apply, which only performance that is "doing" can give.'* Drucker is speaking of the higher levels of education but the implications apply to the whole range, and will become even more relevant in the future. Thus Liepmann, in her survey of the apprenticeship system, writes, 'As automation spreads, in particular, many workers will have to expect that they cannot stay in one occupation during the whole of their working lives; in dynamic conditions occupational and industrial mobility of labour is essential. This consideration greatly enhances the importance of technical and general education; for it is education in all its forms (rather than the possession of specific skills) that facilitates mobility and adaptability.'†

This acceleration in the rate of change is, however, not evenly distributed throughout even the most highly developed societies. In some aspects of our lives, particularly in those more directly affected by science and its applications, it can be very rapid; to make a list of all the new materials and commodities, tools and machines, techniques and processes which have come into use in our own lifetimes would be a formidable enterprise. But in other aspects change has been much less rapid—in law and politics and religion, for example. The institutions in these areas cling more firmly to their traditional ways and do not discard or modify them readily. This may lead to the existence of time lags and serious contradictions between new ways and old, at any point where these different institutions impinge on each other. Some of the most pressing problems which face mankind today arise from this failure to bring the new and the old effectively into line. The discovery of atomic energy and the development of the powers it puts at man's disposal obviously calls for higher forms of political organisation than the traditional pattern of nation states, each claiming sovereign powers and the right to defend its interests by the use of force. H. G. Wells referred to the race between education and catastrophe and the point of this is even clearer today. Clearly education, in the broadest sense, could be used to prepare for more rapid changes in the areas which lag behind, and not as it largely is today to consolidate sentiments and habits which increase rather than diminish the danger threatening mankind. Another aspect of this problem is the urgent need in the more developed societies for bridging the gap between the minority whose work initiates technological changes, the specialists in research and discovery on the one hand and on the other the great majority who may benefit or suffer from the products of change without understanding much of what is involved. Within this wider problem there is a subsidiary one which arises from the difficulties of communication among the specialists themselves. We continue to pay lip service to the values of a general liberal education but in terms of what is actually done in most institutions for higher education it appears to be a lost cause. It is not the specialisation itself that we should deplore but the compartmentation that accompanies it. If the specialism is pursued in its own context only the result is not education but training. Education takes place only when there is a constant relating of what is being specially studied at the moment with other fields of study and with the general background of social life. It may be that the outstanding student, given a favourable cultural environment, can do this relating for himself. But the majority of students cannot be expected to do this unaided, certainly not in face of all the pressures operating in the opposite direction.

A special problem concerning the relating of new and old arises because western civilisation, in its distinctive modern aspects, its science and technology, cannot be said to have evolved any distinctive and fundamental ethical values. This is not to deny that science has its own ethical standards which are applied by the good scientist within the field of his work; but it is certainly not clear how these standards might apply in the field of political and social life where the products of science are utilised. For our guidance in this field we have to resort to moral insights and values which derive from earlier pre-scientific traditions. We have as educators therefore to face the task of translating these traditional ethical and social values into modern terms; in forms which will make sense to young people growing up in the world of today. In particular, we have to work out how these values apply not only in small face-to-

* P. Drucker, *Landmarks for Tomorrow*, 1958, p. 107.
† K. Liepmann, *Apprenticeship*, 1960.

face communities but also in our immense, complicated industrialised States. To be effective in such conditions, they have to be institutionalised in a modern context, as for example we might say that some of the basic principles of Christianity are institutionalised in the Welfare State. Unless this sort of linkage is specifically made in the minds of the young, they may well feel that the adult advocacy of these traditional values is both anachronistic and hypocritical.

Reference was made earlier in this article to the marked increase in social mobility in the developed societies, as one consequence of the technological changes. The child's future position, status and rewards are much less influenced than formerly by his place of birth and his parents' position in the society. It is indeed generally accepted among us that it is best for the society as well as for the individual if each child can be helped to take a place in society in which he can utilize his special capacities and skills. We have therefore come to use our educational system as a sorting device, as the best and fairest way we know of deciding who goes where. It is not, of course, the only means we use for deciding this, but the use of educational institutions for this purpose has increased to such an extent that in many people's minds it amounts to an obsession. Now there is an obvious danger that the need for selection, classification and streaming may divert energy from and distort the fulfilment of other educational aims. In particular it may happen that the child's and young person's ultimate destination may become prematurely determined by short-term tests and assessments. It may well be that, in a given case, the procedure for selection at eleven is as efficient as it can be made; even so there is a limit both to the degree of discrimination and to the time range over which such a test can operate as a predictor. Furthermore, we know that in theory the child should take examinations in his stride at certain crucial points where choices have to be made; but in practice many children, and certainly the brightest, are being examined and arranged in competitive order continually; in some schools every day is judgment day and examinations determine syllabuses and provide the main incentives for work. The private school, reported on in 'Panorama', which devotes itself exclusively to coaching for the eleven-plus from the age of seven, is an extreme case but only because it is in a position to respond freely and wholeheartedly to the pressures which exist in the society served by the school. Another current example, applying to a later age, is that it appears to be thought impossible to get the brightest young people of our society to achieve reasonable efficiency in the use of their own language unless there is an examination in this 'subject'.

I turn now to some areas of our social lives where changes have taken place less dramatically than those in the field of science and technology and operate more gradually over a longer time span. In primitive societies and in our own before the changes associated with the industrial revolution, the immediate neighbourhood provided the setting of the individual's life and most of the commodities that he needed. The child grew up in this closely knit, organic community, in close contact with the basic processes; most of what he needed to know about life as an adult was there on his doorstep. But in the large urban aggregations of our society today, he sees at first hand only a small part of the whole; commodities come from the ends of the earth, the processes which produce them and transport them may be complicated and distant; he depends on a vast network of impersonal relations and contracts with people he may never see. For our life-lines we no longer depend mainly on face to face relations with our neighbours but on intricate systems of organisation and communication. Education today therefore has the task of giving the citizen some understanding of those vast and complicated arrangements and of the basic technical and social processes on which modern civilisation depends. Only a small part of this can be done through direct observation and first-hand experience, though no doubt schools would benefit from being less segregated than they often are, going out more into the community and bringing representatives of the community more into the school. Even so much of necessity has to be done more indirectly and by second-hand presentation or dramatic reproduction. If a tithe of the technical resources so freely used today in the entertainment industries were available for schools, it would make a considerable difference in the effectiveness of the learning.

We next note that over this same time span there have been marked changes in the nature of the home and family in which the child learns its first

lessons in life. For many children today, the family means its own parents and at most one or two other children, the nuclear family not the extended family normal in less developed societies. This means that the child's social relationships in the early stages of experience are more restricted and the ties perhaps more intense. Then again the modern home is more in the nature of a service station and much less the production centre that it once was; and families often scatter as individuals for both work and play. Indeed the tendency to regard the individual as the basic unit rather than the family or clan or tribe is a marked feature of modern society. All this means that the basic social experiences in the formative period of early life are different and that there is some loss in this as well as gain. The school may have in some ways to supply the deficiencies of the home and provide a richer network of social relationships than the child can get elsewhere. There is indeed considerable recognition of this at the nursery and infant stage of education and here the contacts between school and home are often close and fruitful. Later on it is not an unfair comment to say that schools become progressively less like extended families and more like the factories of our society where goods are processed and classified and streamed with a view to effective large-scale production.

We should also be aware that there have been marked and dramatic changes within living memory in the role and status of the age groups in our society. There has been a marked rise in our evaluation of youth and a change in our whole concept of the nature of childhood and youth and of the rights and responsibilities of young people. We have moved in three generations from a society of which, like the traditional Chinese, it might be said 'the older, the better' to one whose slogan might well be in some respects at any rate 'the younger, the better'. Such changes are not, of course, uniform and systematic throughout a society, and we face the problem of older and newer concepts and practices at conflict with each other. This problem often becomes acute in the period of adolescence, which tends to be in our society a no-man's land between childhood and the adult stage. The period of preparation for adult living in our complex society has been lengthened for many far beyond the point where they will be content to be regarded as children and kept in economic and social dependence. With the ever-growing demands for specialised education and training this trend is likely to continue and the problem of giving young people status and rewards commensurate with the new evaluation of youth is one of the most urgent which faces us.

The employment of technical resources in the fields of persuasion, propaganda and entertainment is another characteristic of our society which must cause concern to educators. It means that we are employing vast and expensive educative, or mis-educative, resources in fields outside the formal educational system and not subject to the same professional controls. There are some profound contradictions in the values embodied in the two systems and it might appear to an outsider that we are expending a lot of money in schools and colleges to bring up young people in what we believe to be the right way: and on the other hand allowing even more money to be spent by other agencies to undo the effect of the first. It is not easy to see the solution for this problem: we dislike the idea of censorship and control but a more serious effort is clearly needed to get the advertising and entertainment professions to realise that they have an educational responsibility. Meanwhile it is imperative that the schools include in the education they give some specific training in critical awareness in these fields and in the development of cultural and aesthetic standards.

In conclusion I would stress the need for longer term planning in education, and planning which takes full account of the sociological factors involved. We have indeed made large and creditable advances in the expansion of all branches of education since 1944 but it has been a hectic business of going from one emergency to another, of evolving crash programmes overnight to meet an urgent new problem in the rapidly changing social scene —birthrate changes, shortages of scientists and technicians, changes in the marriage age and so on. Adequate research services which would enable us to anticipate these changes a little more in advance are not the least among our needs.

BRAIN AND INTELLIGENCE

By Dr. HUGH JARVIE *Department of Psychological Medicine, University of Liverpool*

In the early part of the century the cortical 'brain-mappers' localised, in restricted areas on the brain surface, many components of our mental life.[1] Although we now reject these charts of brain function as naïve and unconvincing, we are still very much concerned with trying to discover the kind of cerebral organisation that underlies our intellectual processes. One question is fundamental to this research: Is intelligence primarily a function of a specialised part of the brain, or is it inseparable from the activity of the brain as a whole? The extent to which we have succeeded in answering this question is the subject of this paper.

The Frontal Lobes

For almost a hundred years the frontal lobes have been widely regarded as the intellectual centre of the brain. The credit for first suggesting this is generally given to Hitzig,[2] although some sixty years previously Bouillaud[3] had observed that, following their excision, animals became 'idiots'.

It is not altogether clear why Hitzig should have chosen the frontal lobes, for, at that time (1884), the experimental evidence then available suggested, if anything, the opposite view. Following the ablation of cerebral tissue in dogs Goltz[4] had reported that the greatest intellectual loss appeared after removal of the posterior quadrants of the brain; this, he concluded, because of their greater mass. It may be that Hitzig, who had been responsible with Fritsch[5] for first identifying the motor cortex, was impressed by the resistance of this other part of the forebrain to electrical stimulation. What more ideal situation for our thought processes could there be than this large area which, when stimulated, produced no external activity? He did not, however, place all intellectual functions in the frontal lobes, but only what he called 'abstract thinking'; for the rest, he agreed with Munk[6] that they should be sought for in all parts of the brain.

How far are we justified today in accepting this view of frontal-lobe function? Clearly we can only do so, not in the light of nineteenth-century speculation, but upon the basis of the clinical and experimental evidence now in our possession. When this evidence is examined it can be seen to follow two well-defined, but separate, paths. On the one hand there is that derived from the results of intelligence testing, and on the other, that based upon the general behavioural changes that follow lesions of the frontal lobes.[7, 8]

Intelligence and Behaviour

Frontal-lobe behaviour is often socially disturbing because it is frequently inappropriate in the setting in which it occurs. This has been taken to indicate that certain complex intellectual processes are no longer functioning. Brickner[9] states that these are synthetic in character, responsible for the building up, from simple thought processes, of the concepts necessary for planned conduct. Goldstein[10, 11] considers them to be processes which, in a behavioural situation, abstract from that situation, the elements that will ensure appropriate behaviour.

These formulations are hypothetical; do they, in fact, provide a reasonable explanation of what happens when the frontal lobes are damaged?

If concept formation is so disturbed that it produces serious changes in behaviour, then it should also result in intellectual unawareness of the inappropriate nature of the behaviour. In a study of the changes in behaviour that resulted, in a group of men, from wounds of the frontal lobes, I have shown that this is not invariably so[8]; many of the men with characteristic personality

changes were only too well aware of the disturbing nature of their behaviour, and were emotionally concerned about it.

On the other hand, if processes of abstraction are at fault, then it should be possible to demonstrate failure to abstract in simple test situations. Goldstein[12] maintains that this can be done on special tests—the Goldstein-Scheerer tests; but his results await substantiation. In some of the men with frontal-lobe wounds it was possible to demonstrate, on ordinary intelligence tests, that they had not lost the ability to abstract at their pre-injury level.

What is perhaps the most serious objection to these hypotheses is that they imply that the control of behaviour depends upon intelligence. Now this is a proposition that few of us are prepared to accept. We cannot conclude that because a man's behaviour is socially unacceptable that he is unintelligent; he may be, but not necessarily so. The changes in behaviour that follow injury to the frontal lobes are, in my view, comparable to psychopathic behaviour: in the psychopath adequate control of behaviour has never been acquired, in the man with a lesion of the frontal lobes control is defective because the cerebral mechanisms, normally responsible for that control, have been damaged. These mechanisms are inhibitory rather than intellectual.

Intelligence Testing

If the changes in behaviour are not arising out of concomitant changes in intellectual functioning can we, nevertheless, demonstrate losses in intellectual capacity after frontal-lobe damage by means of conventional mental tests? Before considering the answer to this question if would be as well to look at some of the difficulties involved in what, at first sight, appears to be a relatively simple, and straightforward, procedure.

Intelligence tests measure intelligence in different ways. Some tests, for example those of the Binet-Simon type, do so by assessing, in large measure, the subject's level of acquired experience in the form of vocabulary or general information; others, such as Raven's Progressive Matrices, measure the subject's capacity to solve problems set in a novel situation. If acquired experience of a verbal kind is not stored in the frontal lobes, and we have reason to believe that it is not, then no deficits will be demonstrated on tests that are largely concerned with verbal reproduction; deficits in problem-solving may exist, but would only be shown if the appropriate kind of test is used. It is never enough in research of this kind merely to give tests, and accept the answers, without asking what those answers mean in terms of specific intellectual functions.

We must also make sure that we are identifying permanent, and not temporary deficits. Recovery from brain damage takes time, and this is especially so after injury to the frontal lobes where the period of recovery is measured in months rather than weeks. Intellectual deficits can sometimes be shown to be present in the weeks after frontal-lobe damage that cannot be shown to exist months later.

Unless intellectual changes are obvious it is sometimes difficult to be sure that they are present at all except where accurate information is available of the subject's intellectual level before the injury happened. Occasionally mental testing is carried out before the brain damage occurs, as, for example, prior to a prefrontal leucotomy operation; only in exceptional circumstances is this kind of information available in other cases, and, in its absence, other methods have to be employed to estimate the pre-injury level of intelligence. These methods often leave much to be desired.

Brain injury is rarely selective, and even when a standard operative procedure is used, such as that of leucotomy, the extent of the brain damage, and even its situation, may vary significantly from case to case. It is obvious that, in assessing the significance of any intellectual deficits, this must be taken into account as well as the fact that a certain area of the brain is the site of the damage.

In view of what I have just said, it is perhaps not surprising that the very numerous results of mental testing, in every kind of frontal-lobe lesion, should be so equivocal. It is clear, however, that very severe damage can occur within the frontal lobes without it affecting performance on standard intelligence tests. This fact has been reported too often to be ignored, and, I was able to confirm it in the men with frontal-lobe wounds.[7] Many of these men did as well on problem-solving tests after they were wounded as they did before; in some cases they even did better. It must be

accepted that mental tests sample only limited aspects of human intelligence, yet on the basis of these findings it seems improbable that the frontal lobes can have any vital, or exclusive, role to play in our intellectual processes.

Equipotentiality and Mass Action

The idea that intelligence is the prerogative of one part of the brain has frequently been opposed. 'All intellectual faculties reside exclusively in the brain, but all these faculties occupy the same place.' So wrote Flourens[13] in 1842, no doubt protesting against the absurd localisations of the phrenologists, then much in vogue. The belief that intelligence could be localised in the brain was to Cajal[14] a chimaera.

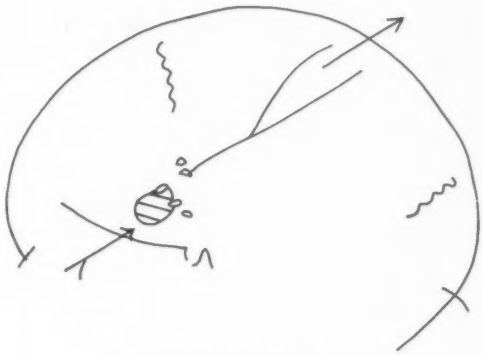
The modern exponent of these views is K. S. Lashley[15]: His experiments on the effects of cerebral lesions on intelligent behaviour in the rat have widely influenced psychological thinking; what he says is not always free from obscurity, but the practical issues are clear.

He took as his measure of the rat's intelligence its capacity to learn a maze. Then by selective removal of cerebral cortex in a large number of animals he sought the answer to a simple question —does the acquisition of the maze habit depend upon localised cerebral mechanisms, and, when it is acquired, can it be destroyed by the removal of tissue from the part of the brain concerned.

The results of this research are well-known. The acquisition of the maze habit did not apparently depend upon a specific part of the cortex, but the failure to acquire the habit was proportionate to the amount of tissue destroyed; with a given extent of cortical lesion there was increasing difficulty in learning to run the maze as the mazes increased in complexity. Once the habit has been acquired its loss also depended, not on the location of the lesions, but on the amount of cortical tissue removed. Lashley concluded from these experiments that the cerebral cortex acts as a whole (Law of Mass Action), and in spite of its structural heterogeneity, is functionally homogeneous (Principle of Equipotentiality).

Problem-solving

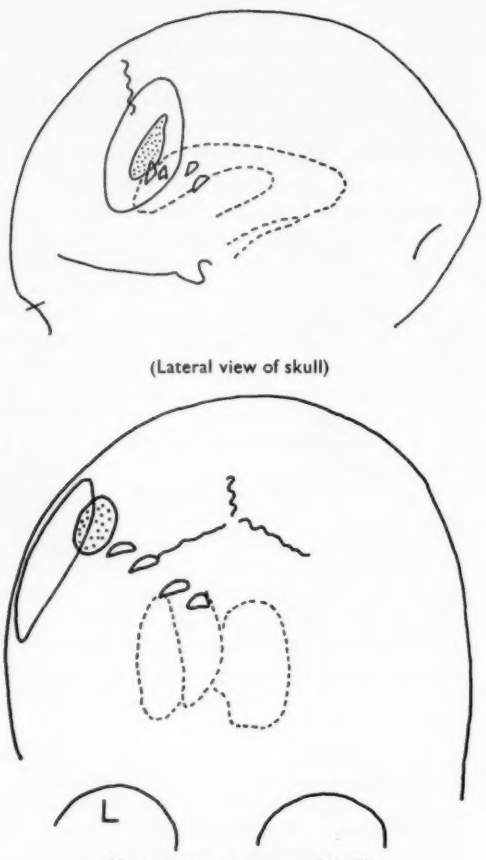
To the student of human neurology these results, albeit from the rat, are, to say the least, disturbing. The idea that all the cerebral cortex is in action when problems are being solved is not difficult to accept; but the notion that acquired experience is distributed throughout the cerebral cortex, much in the same way as ripples are on the surface of a pool, is contrary to our usual experience of human cerebral organisation. We cannot, however, dismiss Lashley's work as irrelevant to the



(Lateral view of skull)

(Antero-posterior view of skull)

Fig. 1.—Tracings of skull radiographs in Case 8. Self-inflicted injury. Bullet entering right frontal lobe 3 cm. behind right eyebrow and passing through-and-through: exit right parietal region.



(Lateral view of skull)

(Antero-posterior view of skull)

Fig. 2.—Tracings of pre-operative skull radiographs in Case 17. Bone fragments driven into the posterior part of the left frontal lobe to a depth of 5 cm.

study of man's brain function without examining it in the light of such evidence as we possess from investigations of human brain damage.

In examining men with wounds of the brain (including wounds of areas of the brain other than the frontal lobes) I wanted to find out what kinds of brain damage caused these men to fail conclusively on problem-solving tests.[16] When these cases were identified, and the anatomical findings were studied, they were seen to form two fairly well-defined groups. The first contained those cases with severely destructive wounds—in these men the missile had passed through, or almost completely through, one hemisphere—Case 8 (Fig. 1). In the other group, the missile had passed deeply into the brain in either the posterior frontal or anterior parietal region—Case 17 (Fig. 2).

In both these groups the actual damage to the cerebral cortex was relatively small; the wounds exerting their main effect by disrupting the pathways running in the white matter. In doing so they isolate different areas of the cerebral cortex from one another.

The failure on the part of these men to solve problems is most probably the result of this loss in cortical integration; as such it can be reasonably compared with Lashley's findings in the rat.

Acquired Experience

Was there in these men, in addition to their decreased capacity for solving problems, an equivalent loss in acquired experience? To have assessed this at all comprehensively would have been a task of overwhelming difficulty; but some information was obtained about one kind of learned experience.

These men were given a vocabulary test, and on this test they performed very adequately. It was possible to take this a little further in Case 8.

When this man was in hospital it was observed that he kept a pile of books beside his bed. The books were all of recent publication consisting of novels, biographies and war memoirs. In view of this man's obvious mental loss on clinical observation, in attempts at constructive tasks in the occupational therapy department, and on the problem-solving tests, I was interested to find out whether he really understood what he was reading in these books. I asked him to write a review of one of the books; and he did this very competently. Later on I was able to read an equally competent article that he published in the hospital newspaper. In these written productions there were slight defects, but no more than could adequately be accounted for by his cultural background.

I think we can only conclude that verbal experience, often learned at no small cost, was in this man not distributed generally throughout his cerebral cortex but relatively localised in the cortex of one-half of his brain.

What I have described is, of course, a matter of ordinary clinical experience, but it did surprise me that this man could organise verbal material so well when at the same time he showed so marked a deficit in problem-solving.

Intelligence and the Brain

Is intelligence a function of part of the brain or is it inseparable from the activity of the brain as a whole? This was the question that I posed at the beginning of this paper. In view of what I have said subsequently it clearly requires reappraisal. It is impossible to regard intelligence as an entity; we may not even be quite sure exactly what it is. As for the brain, of course it works as a whole, as does any living dynamic organism. In research of this kind all that we try to do is to interpret the pattern of cerebral organisation that underlies different kinds of intellectual function. It would indeed be strange if these complex and highly differentiated functions were represented in that pattern in exactly the same way.

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INCREASING THE CALVING RATE IN CATTLE BY HORMONAL THERAPY

By Dr. IAN GORDON *Milk Marketing Board, Cattle Breeding Sub-Centre, Caersws, Montgomeryshire*

The number of eggs produced at time of mating in our farm animals is controlled by gonadotrophic hormones secreted by the anterior pituitary. When this fact was realised, some 30 years ago, it was at once apparent that they might eventually be employed as a means of controlling the reproductive performance of the animal to fit the requirements of the stock-owner. American workers, in the early thirties, found a useful source of one of the two important gonadotrophic hormones to be the blood serum of the pregnant mare, and this discovery set in motion a number of studies in the use of the material (Pregnant Mare Serum—P.M.S.) in the control of animal fertility. Much of the early work was conducted in America and Russia and was directed towards overcoming the problem of seasonal breeding in sheep. It was not until the years of the last war that serious attention was turned towards using P.M.S. to encourage multiple-births in cattle.

Sir John Hammond and workers at Cambridge showed, in 1942, that it was possible to induce superovulation in the cow by the injection of P.M.S., but, owing to limited facilities for large animal research, it was not possible to take work beyond the laboratory stage until the Milk Marketing Board decided to examine the technique as part of the many studies which they conduct in cattle fertility. In 1958, when it was decided to commence work, a large number of the cows put to A.I. in England and Wales went to beef bulls (mainly Hereford and Aberdeen-Angus). In the few years since their introduction to A.I. Centres, a great increase had been observed in their use, not only in dairy cattle but, in the rearing areas, in beef cattle also. It was becoming apparent, in 1958, that the proportion of dairy cows put to beef bulls could not be taken much higher because of the need for a regular supply of dairy heifer replacements. There was a steady demand for home-produced beef, and 1958 seemed an opportune year to examine the commercial possibility of encouraging cows to produce twins.

Late in 1958 the M.M.B. announced that they were to introduce a 2-year field trial to test the use of P.M.S. as a means of increasing the calving rate. So far as was known, this study was the first of its kind to be attempted, and the present paper deals with some of the interim results from the work. The trial has now been in operation for 18 months, and a position is now being reached where some of the statements about the value of the P.M.S. technique are becoming meaningful. The method of treatment which the M.M.B. sought to test consists of a single, subcutaneous injection of P.M.S. given in the late stages of the cow's breeding cycle, i.e. at a time when development of the egg, due for release at the next oestrus, is getting under way.

Area Chosen for the Study

The field work is conducted from Caersws, Montgomeryshire, a village lying in the heart of the traditional beef-rearing area of Mid-Wales. In 1958, some 30,000 Hereford bull inseminations were carried out in the area, and it was known that many of these were in the herds of farmers mainly concerned in rearing. The area covered in the work takes in the counties of Montgomery and Radnor and parts of Merioneth, Hereford, Brecon and Shropshire.

In choosing this particular area for starting the work, it was borne in mind that many farmers engaged in beef-rearing have cross-bred cows

capable of producing enough milk to support two calves during their lactation. Custom on many farms is to buy a second, cross-bred calf to rear on the cow after calving. What was to be attempted in the trial was a possible saving in the need for the farmer to buy that second calf. It was considered that there would be sufficient economic incentive in this to get the active co-operation of farmers in the area.

Details of the proposed trial were sent round to all those likely to be interested and farmers using A.I. were told that treatment to encourage twins would be carried out free of charge. In drawing the attention of the farmer to the trial, emphasis was placed on the point that each injected cow would be examined in early pregnancy to determine whether or not it was likely to produce twins. Prior warning of twins would enable the farmer to apply appropriate feeding and management, something which he is usually unable to do when sets of natural twins occur. Even in instances of unexpected twins, a preliminary survey, conducted in the area, showed that these were often regarded by beef farmers as being satisfactory in birth-weight and vigour. Milk producers, on the other hand, regarded twins as being undesirable, mainly on the grounds that the cow suffered some loss in milking ability in the following lactation.

Aims and Objects

The study fell naturally into two parts: (1) that concerned with the application of the hormone technique in such a way as to induce a reasonable proportion of cattle to carry multiple-calves and (2) that dealing with the practical outcome of twin-pregnancy when animals were given extra feeding in anticipation of twins—an aspect of cattle husbandry hitherto unexplored.

Work in low fertility breeds of sheep, where a similar hormone approach was attempted in the post-war years, suggested that it might prove possible to induce superovulation in about 50 per cent of injected cattle. Allowing for the fact that some proportion of cows would probably fail to carry a single calf, regardless of the number of eggs produced, and that others would fail to conceive at the mating immediately following injection, it seemed reasonable to hope that 33 per cent of cattle could be encouraged to give birth to multiples.

To gain reliable evidence on the efficacy of the technique, over a wide range of genetic and environmental conditions, it was considered that there was need to observe 1000–2000 animals. It was hoped that it would prove possible to inject most of these in the first year of the trial (1959) and to devote much of 1960 to a study of calvings and matters associated with twin pregnancy.

The Farmers' Interest

It quickly became apparent that farmers were not readily willing to enter cows for P.M.S. injection, even where they had expressed themselves as being well satisfied with the outcome of natural twins in the herds. Tales of misfortune with cow and calves, arising from a few instances of natural twins in dairy herds, often tended to overshadow the happier possibilities of the induced, expected twins. Thoughts of flooding the market with calves and sterile 'free-martins' perhaps seemed uppermost in the minds of some. At the end of the first month of the trial, no more than a dozen farmers, out of a possible many thousands had put forward an animal for injection. Then began the task of interviewing farmers, telling them of the trial and trying to relate twins to their own particular farming circumstances. As compared with the previous mass appeals, this 'on-the-farm' approach was much more useful in enlisting the help and co-operation of the herd-owner. Even so, progress in field work was often slow up to the time when the first one or two sets of induced twins were born. After hearing about these, there did appear to be some lessening in the fears surrounding the technique.

Collection of Data

In treatments already carried out, most cows have been injected 16 or 17 days after a previous heat period, this heat being reported by the farmer to his local A.I. Office. At time of P.M.S. injection, notes are made about each animal and an attempt made to establish the location of the current corpus luteum. Some 7–14 days after the injected cow has been inseminated, ovaries are palpated *per rectum* to determine number of ovulations. Cows possessing more than one corpus luteum, and which conceive at first insemination, are further examined when they have reached 6 weeks in pregnancy, to establish the number of foetuses.

The 6-weeks stage has been found to be most appropriate for diagnosis of multiple-pregnancy where the conceptus is palpated *per rectum*.

A record of examinations and observations is kept for each animal, so that those cows that fail to remain pregnant or are lost to the trial can be accounted for at any particular time. Where practicable, multiples are weighed soon after birth and information gathered about the cow's condition and of incidents which may arise at calving. Finally, note is taken of the return to regular breeding of the cow after multiple pregnancy.

Entry of Cattle

At the end of August 1960, 450 cattle have been entered for P.M.S. injection, these being located on 286 farms. Most farmers have entered only one cow from the herd; a few have tried as many as six or seven. Nearly all the entries are commercial, non-pedigree cattle maintained in accord with local custom, and there is no reason to believe that the animals are unrepresentative of the cow population in the Mid-Wales area. Information is at present available on the response of 386 cattle. The first consideration is ovulation rate in relation to treatment and animal circumstance; secondly, the question of 'Silent' heat; thirdly, conception; fourthly, egg and foetal loss after mating; and finally, the calvings which have occurred.

Ovulations

In encouraging cattle to give birth to twins, two different approaches have been examined:

(1) Using a low dosage level of P.M.S. in an attempt to keep number of ovulations within a narrow range—i.e. getting cows to produce two eggs only in as many cases as possible;

(2) Using higher doses for inducing a response to the P.M.S. injection, regardless of egg number, and seeing how far egg and foetal loss in pregnancy go in reducing the number of calves finally carried to term.

The second approach gives scope for study of possible ways of controlling litter-size to two in cattle possessing more than that number in early pregnancy.

Ovulation data are available for 329 cows which were injected, came in oestrus and inseminated, then examined for evidence of ovulations at the mid-cycle stage. Five dosage levels of P.M.S. have been used (800 i.u. to 2000 i.u.), and there is no evidence that treatment leads to any change in the normal ovulation process. Follicles which have matured to ovulation size but failed to ovulate, are occasionally noted in cattle injected with doses of 2000 i.u. but are rarely found in animals receiving lower doses. Even where unovulated follicles are noted, there is nothing to suggest that they give rise to defects in the process of ovulation or fertilisation.

TABLE 1

THE RELATIONSHIP BETWEEN DOSAGE LEVEL AND OVULATION RATE

Dosage level (i.u.) P.M.S.	*Cattle examined*	*Range of ovulations*	*Average number of ovulations*
800	99	1–5	1·42
1000	141	1–15	1·74
1200	32	1–17	2·68
1600	7	1–15	3·57
2000	46	1–25	4·37
All doses	325	1–25	2·15

Present results strongly suggest that there is a dose-response relationship over the dosage range employed, and that some measure of control over the extent of superovulation lies in the amount of P.M.S. injected. The fact is shown in Table 1; there is no difficulty in inducing cattle to produce an average of two eggs.

The higher the dosage level of P.M.S. employed, the greater the variability in the number of ovulations in those animals which show a response. This is shown in Table 2. The percentage of cattle responding rises from 32 per cent at the 800 i.u. dosage level to 50 per cent at 2000 i.u. The overall percentage responding is 36. With

doses of 800 i.u., cows that respond do so usually by producing two eggs only. As dose is increased, more cows produce three eggs or higher. With 2000 i.u., it is observed that eight times as many cows tend to produce four or more eggs than at the lowest dose.

cattle with short oestrous cycles. Most animals have shown oestrous cycles of 20–21 days and only 1 per cent of cows have come in oestrus prior to the date on which hormone was due to be administered. Unlike in sheep, it appears that P.M.S. injection in cattle does not shorten normal

TABLE 2

NUMBER OF OVULATIONS IN RELATION TO DOSE OF P.M.S.

P.M.S. dose (i.u.)	*Number of cattle examined*	*Number of ovulations*				
		0	*1*	*2*	*3*	*More than 3*
800	100	1·0	67·0	26·0	3·0	3·0
1000	144	2·1	63·2	20·8	5·5	8·4
1200	32	—	63·6	9·3	9·3	12·4
1600	7	—	43·2	28·8	14·4	14·4
2000	46	—	50·0	15·2	8·7	26·2
All doses	329	1·2	62·0	20·7	5·8	10·6

There is a tendency for the percentage of cows producing only two eggs to fall as dosage level increases. It is possible that the injection of a higher dose of P.M.S. often encourages those cows which would respond anyway to do so by producing more eggs. Increasing the dosage level is not an effective answer to the problem of trying to induce a higher percentage of animals to have double-ovulations. As far as present results suggest, there may well be some proportion of cattle which will not respond to P.M.S., probably regardless of dosage level employed.

cycle duration (taking as normal 21 days), even where a high 2000 i.u. dose is employed. This is shown in Table 4. In cows which have shorter cycles than normal, and come in oestrus within 2 days of P.M.S. injection, the percentage responding is very low. Where dosage levels of 800–1600 i.u. P.M.S. are employed, it is now considered almost unnecessary to examine animals, if they show oestrus within 2 days, for the possibility of additional eggs is so slender. Because of the variability in oestrous cycle length, and apparent need for a 2-day period of P.M.S.

TABLE 3

PERCENTAGE OF CATTLE PRODUCING ADDITIONAL EGGS IN RELATION TO TIME OF P.M.S. INJECTION IN THE OESTROUS CYCLE

	Day on which P.M.S. is given in oestrous cycle					
	15	*16*	*17*	*18*	*19*	*All days*
Number of cows examined	10	102	210	6	1	329
Cows responding	1	38	78	2	1	120
Percentage responding	10·0	37·3	37·2	33·3	100·0	36·5

Most cattle have been injected with hormone either 16 or 17 days after oestrus and, as shown in Table 3, the percentage responding is similar. Results for days earlier or later than these are not available in any number, but certainly day 15 has not been associated with a satisfactory response.

It seems clear that the P.M.S. technique can be applied without undue practical difficulty from

stimulation for induction of response, it is clear that the present technique can only be successful in a limited percentage of cases.

Information is available on the response of the cow according to the time of year at which injection was given. With the low dosage levels (800–1000 i.u.) of P.M.S. there is some suggestion that response is poorest when changes in day-length

are minimal. If results are grouped into the Quarters of the year, response is higher in the first and third quarters than in the second and final. Where the high (2000 i.u.) dose is used, seasonal differences in response are not apparent.

Injections have covered a fairly wide range of cattle, and these have been used by the farmer in different ways. While most have been engaged in rearing one or two calves, some have been milking and others 'dry' cows. There is a suggestion that 'dry' cows respond more readily than lactating animals. Cattle that are milked respond in a similar percentage to that observed for animals rearing one or two calves. The poorest response is found in cows used in the multiple-suckling of calves, where they are rearing groups of three or four. Results, in general, suggest that lactation differences emerge from results when ovulation response is considered in relation to factors such as feeding and the interval between previous parturition and injection in the lactating animal.

Studies in the reproductive physiology of the cow have already drawn attention to the fact that the right ovary is much more active than the left, and this observation is borne out in present results. Furthermore, in cattle which respond to P.M.S. by producing two eggs, and where ovulations are confined to one ovary, the right is the one usually involved. This is shown in Table 5. In cows producing more than two eggs, it is often observed that the ovary possessing most corpora lutea is the right. This particular pattern of response may have a bearing on the survival of eggs during the early part of pregnancy, and is discussed later.

TABLE 4

AVERAGE DURATION OF THE OESTROUS CYCLE IN RELATION TO P.M.S. DOSE

	Dosage level of P.M.S. dose (i.u.)					
	800	*1000*	*1200*	*1600*	*2000*	*All doses*
Number of cattle examined	98	142	32	7	44	323
Average cycle duration (in days)	21·01	20·98	21·15	20·57	20·78	20·96

affects the ability of the animal to respond to exogenous gonadotrophin.

Age of cow has varied from 2 to more than 10 years, but there is little difference in the percentage responding where age factor is considered. Cows which have given birth to natural twins prior to treatment respond in the same way as those with a history of single calvings. Cattle, at the time of injection, are scored for general fitness and body condition, but analysis of ovulation data, bearing these factors in mind, reveals little of significance. Records on size and state of activity of the ovaries, taken at the time of hormone injection, indicate that superovulation occurs less frequently in cattle where both ovaries are below average size than in those where both are normal.

Most cows have been Hereford Shorthorn or Hereford Friesian crosses, but there has been opportunity to study response in pure-bred Hereford, Shorthorn and Friesian cattle. No association between breed and percentage responding is shown in present results. No striking

Silent Heat

The P.M.S. technique can only be useful in encouraging multiple-births where the cow comes in oestrus within a few days of injection. Should the first, post-injection, oestrus be missed, or the animal fail to show the usual symptoms of oestrus, then at subsequent matings ovulation rate is normal. There is no evidence of any 'carry-over' effect in sheep where P.M.S. is employed, and this is true in the cow. This does mean, in using the present technique, that a problem to be faced is that of 'Silent' or 'Still' Heat, i.e. the condition where ovulation is unaccompanied by oestrus.

Of the cows injected so far, the incidence of Silent Heat has been about 15 per cent. It occurs at all dosage levels of P.M.S. and at all stages of the cycle at which injection is given. Cows receiving low doses (800–1000 i.u.) tend to suffer more than those receiving high doses (1600–2000 i.u.), while those injected earlier in the cycle (15–16 days after oestrus) suffer less than those

treated later in the cycle. There is probably an association between Silent Heat and lactation. If data are examined to take account of the use made of the cow by the farmer, it is observed that 'dry' cows are less likely to suffer (6·3 per cent incidence) than those lactating, and that cows engaged in multiple-suckling show the highest incidence (27 per cent). Analysis of data for factors such as age, breed, condition and season of the year shed little light on the reasons underlying the occurrence of 'Silent Heat'.

The present view is that the injection of P.M.S. does not give rise to the condition, but that it probably does little to relieve it. It is known that the condition may occur in normal animals, particularly in those suckling calves. Most animals, suffering from the condition after injection, show a normal oestrus after one ovarian cycle (i.e. 25–26 days after injection), but 33 per cent of them may not return to regular breeding until a number of ovarian cycles has passed. Cows showing Silent Heat are usually checked for evidence of ovulations at the mid-cycle stage following date of first anticipated oestrus. It is found that the occurrence of multiple-ovulations is much less common, where low hormone doses are used, in such animals than in those which come in oestrus in the normal way.

Since there is a tendency for Silent Heat to occur in cows which normally have heats of rather low intensity, advice to farmers is that they should not enter such cows for treatment—only those which are in the habit of showing strong symptoms of oestrus.

Conception

Of those cattle which have been injected, data are available for 288 that have passed at least 2 months from the time of first insemination. The percentage of these found to be pregnant when examined (at approximately 42 days) after first mating is 77·1, a figure which compares favourably with that for ordinary cattle put to A.I. in this area.

Figures on conception in relation to dosage of P.M.S. employed show little difference in the groups, and the percentage conceiving is as good in cattle that produce many eggs as in those that produce a single. This information is in Table 6. It seems reasonable to conclude from present figures that P.M.S. therapy does not give rise to defects in the normal fertilisation process. Cows which produced six or more eggs were all pregnant when examined some 6 weeks after mating. If the normal fertilisation process is greatly disturbed, in cattle producing a large number of eggs, then it would be expected that total failure would occur and the cow be found non-pregnant at time of examination. While there can be no certainty, in the absence of egg recovery studies, the present indications are that most eggs are fertilised even where a large number is produced.

TABLE 5

OVULATION IN THE RIGHT AND LEFT OVARIES

Single-ovulating cattle

	Location of ovulations	
	Left ovary	*Right ovary*
Number of cattle examined	83	122
As percentage of all	40·5	59·5

Twin-ovulating cattle

	Both in left ovary	*One ovulation in each ovary*	*Both in right ovary*
Number of cattle examined	7	40	21
As percentage of all	10·3	58·8	30·9

Cattle shedding three and more eggs

	Most in left ovary	*Equal no. in each ovary*	*Most in right ovary*
Number of cattle examined	12	6	34
As percentage of all	23·1	11·5	65·4

In the ewe, there is some evidence that conception suffers where a rather long interval separates time of injection and onset of oestrus, but there is no evidence for this in the cow. Animals which do not show oestrus until 9–10 days following injection appear to conceive just as ably as do those in oestrus within a day of injection.

TABLE 6

PERCENTAGE CONCEIVING IN RELATION TO P.M.S. DOSAGE LEVEL AND THE NUMBER OF EGGS PRODUCED

	Number of eggs produced							
	1	*2*	*3*	*4*	*5*	*6*	*6+*	*All cows*
Number of cows examined	184	62	17	10	4	4	7	288
Pregnant at 42 days	132	54	15	7	3	4	7	222
Percentage pregnant at 42 days	71·7	87·1	88·2	70·0	75·0	100·0	100·0	77·1

	Dosage level of P.M.S. (i.u.)					
	800	*1000*	*1200*	*1600*	*2000*	*All doses*
Number of cows examined	99	127	32	7	23	288
Pregnant at 42 days	77	95	27	5	18	222
Percentage pregnant at 42 days	77·8	74·8	84·4	71·2	78·3	77·1

Egg Loss

The information on number of foetuses surviving at 42 days, in relation to number of eggs produced, clearly show that in many animals there is a heavy loss in eggs in early pregnancy. Data in Table 7 show that 36 per cent of cattle produced additional eggs after injection and that only 18 per cent possessed multiple-calves at 42 days, i.e. 50 per cent of cattle reduce to a single foetus.

At the 6-weeks stage, it would appear that the best chance of producing multiples lies with cows that start pregnancy with a large number of eggs, but as will be later observed, this may not necessarily be so. Already at 6 weeks there is some suggestion that the size of litter sustained is likely to be higher in cows that produce four to six eggs than in those which actually start off with the greater number of ovulations.

Why should multiples be sustained in some cows while in others only a single calf develops? An attempt to examine this question might be made if attention, in the first instance, is confined to those animals which produce two eggs only. Of the sixty-two cattle that had double ovulations, fifty-four conceived and were found to possess either one or two foetuses at 42 days. Figures are given in Table 8. It is of interest to note that survival of both eggs is much more likely in cows producing one egg in each ovary than in those where both ovulations occur in the one ovary.

The suggestion here is that an egg is sustained more readily where it has a uterine horn to itself

TABLE 7

FOETUSES PRESENT AT 42 DAYS IN RELATION TO NUMBER OF OVULATIONS

Eggs produced	*Total cows*	*Number of foetuses at 42 days*						*Percentage of all cows with multiples*	*Percentage of those that conceived*
		0	*1*	*2*	*3*	*4*	*5*		
1 egg	184	52	132	–	–	–	–	Nil	Nil
2 eggs	62	8	33	21	–	–	–	32·3	37·0
3 eggs	17	2	3	9	3	–	–	52·9	80·0
4 eggs	10	3	–	3	3	1	–	70·0	100·0
5 eggs	4	1	–	1	–	1	1	50·0	100·0
6 eggs	4	–	–	2	1	1	–	100·0	100·0
7 and more eggs	7	–	1	4	2	–	–	85·6	85·6
All cows	288	66	169	40	9	3	1	18·1	23·4

than where it is possibly competing for survival with a second egg. It should be mentioned that migration of eggs from one uterine horn to the other hardly ever seems to occur in the cow, although it is quite commonplace in the ewe. It may be that survival of the egg depends on some material which is in limited supply in the cow uterus. The reason why one egg should be able to go ahead and the other die is not at all clear, but possibly one egg has some initial advantage which enables it to develop at the expense of its neighbour.

TABLE 8

LOSS IN EGGS IN RELATION TO SITE OF DOUBLE-OVULATIONS

	Location of ovulations		
	Both in left ovary	*One ovulation in each ovary*	*Both in right ovary*
Cows pregnant at 42 days	6	30	18
Number possessing two foetuses	1	17	3
Percentage to possess twins	16·7	56·7	16·7

The limited data available have been studied to determine whether breed, age and such factors are related to survival of twin foetuses, but there is no present indication that they are. If, indeed, there is competition for materials essential in development taking place between two eggs, then it might reasonably be thought that even keener competition occurs among a much larger number of eggs. There is some evidence to support this view in cows producing many eggs, for they do tend to have smaller litters at 42 days than animals which conceive after shedding four to six eggs. The observed loss in eggs presumably takes place in the first few weeks after conception, for no evidence of abnormally developing foetuses has been found at the time of pregnancy diagnosis 6 weeks after matings.

Loss in foetuses has also been noted after the sixth week of pregnancy. Present results show that 10 per cent of cows possessing foetuses at that stage suffer litter loss in later pregnancy. Losses are concentrated mainly in animals with multiple-calves, and there appears to be some association between the number of eggs produced and loss in foetuses suffered. Cows which produce many eggs appear more liable to sustain total litter loss regardless of the number of foetuses present at 6 weeks. Such litter loss takes the form of resorption rather than abortion. Results, although limited at this stage, do raise the question of the effect on normal pregnancy of many corpora lutea. It may be that the hormone balance necessary for maintenance of pregnancy is unduly disturbed by a large number of corpora lutea. It might be, on the other hand, that pregnancy diagnosis examinations are in part responsible for the total litter losses that occur. After much experience in the field by the Board's Chief Veterinary Officer for Wales, it seems clear that the method at present employed (palpation *per rectum* of the conceptus at 42 days) for establishing multiple-pregnancy is too difficult for widespread application.

It has been noted that some cows fail to carry multiples because of suffering Silent Heat, while others fail because of lack of response to P.M.S.; some cows do not conceive at first insemination and others suffer reduction in litter-number to one. Table 9 attempts to sum up these various losses. Results, as confirmed by calving information, are available for only one group (800 i.u. dose) at this stage.

In this group, two of the cows possessing multiples at 42 days suffered total litter loss later in pregnancy, so that the eventual percentage is 10·7. Until further information is available on the survival of multiples in cattle injected with higher doses, advice to those who may contemplate using P.M.S. is to employ 800 i.u., thereby restricting ovulations mainly to two in those cows that respond. Such treatment may be expected to encourage about 10 per cent of cattle to produce multiples where applied over a wide range of genetic and environmental conditions.

Calvings

The calving of eighty-five cows, which conceived a few days after injection, has now been observed; seventeen of these have produced extra

calves, i.e. 20 per cent. Multiples have consisted of thirteen sets of twins, three sets of triplets and one set of quintuplets. Where twins have been predicted, as a result of pregnancy diagnosis, and where the farmer has followed a suggested feeding policy, twins and even triplets have been carried to term and born healthy and strong. Herd-owners have been encouraged to provide animals with at least an additional 2 cwt. of concentrate feed during the final 8 weeks of pregnancy. Twins born to such cows have been little below the weight of those single calves born to other animals in the herd. With extra feeding, small. The main costs to be faced in the treatment arise in getting multiple-pregnancy diagnosed and in providing the cow with additional feed during the final months of pregnancy. How far such costs can be kept down must await further study. In pregnancy diagnosis, what is really required is a simple and reliable method of establishing multiples at about the sixth month of pregnancy. In feeding, precise information is needed on both the quantitative and qualitative requirements of the animal.

While the use of a low dose (800 i.u.) appears to be effective in restricting ovulations to two in a

TABLE 9

COWS CARRYING MULTIPLES AT 42 DAYS IN RELATION TO HORMONE DOSAGE LEVEL

Dosage level of of P.M.S. (i.u.)	*Number of cattle injected*	*Cattle put to A.I. after injection*	*Number of cattle that ovulated*	*Number of cattle that produced extra eggs*	*Number of cattle pregnant at 42 days*	*Number of cattle with multiples at 42 days*	*Percentage of injected cattle with multiples*
800	121	100	99	32	77	15	12·4
1000	153	127	125	45	95	23	15·0
1200	37	32	32	11	27	7	18·9
1600	7	7	7	4	5	3	43·9
2000	28	23	23	11	18	5	17·9
All doses	346	289	286	103	222	53	15·3

cows have calved down without loss in condition and have returned to regular breeding without delay.

Conclusions

At this stage of the work, thoughts on the efficacy of this particular form of hormone treatment are in no way finalised. There are, however, probably sufficient facts available to say that P.M.S. injection is not likely to induce other than a limited percentage of multiple-births if applied over a wide range of animal and husbandry conditions. The hormone treatment is simple and the work so far shows that this way of encouraging twinning can be carried out satisfactorily within the framework of the established A.I. organisation of the M.M.B. In relation to the value of the produce involved, the cost of P.M.S. injection is majority of cases, the possibility of some cattle carrying triplets or even quintuplets remains. Results indicate that triplets can be carried to term and born strong and healthy, with good feeding. Whether quintuplets can be successfully born, if a cow is found to possess them, must await study under controlled feeding conditions. Where doses of 1600–2000 i.u. of P.M.S. are used, it is likely that a fairly substantial increase in the proportion of cattle carrying multiples can be achieved. The problem in this is the number of cows carrying more than two calves, and there is need for careful study of a means whereby litter-size can be restricted to two. In the present study, an attempt has been made to do this through rupture of 'excess' amniotic vesicles, by manipulation *per rectum*, at the sixth week of pregnancy. There is, however, no present indication that this is likely to provide an effective solution.

BRITISH ASSOCIATION NEWS

Norwich—The Present and the Past

Despite the pressures of a revolutionary age and its own lively development, there is much about Norwich—compared with a modern industrial city—that seems unchanging. Its position as the chief market of a great agricultural region, for instance, goes back to Saxon times; the atmosphere of an old and gracious cathedral city is in harmony with the magnificence of the Norman Cathedral; and more fully perhaps than any other English provincial city it has remained the capital of its province and developed a distinctive local culture of its own. It may be this quality of permanence, the sense of returning to a familiar scene, that makes the memories of the Association's last Meeting in Norwich, twenty-six years ago, seem especially fresh. A glance at the published programme or the list of members attending is like thumbing through the pages of a family album. Names that are so well known in the Association today appear plainly—their knighthoods, honours and F.R.S.'s yet to come; but it is more fascinating still to note the thread of likeness in the subjects discussed that can be detected running through the two previous Norwich Meetings and which links up with the programme being planned for this year.

Our President in 1961, Sir Wilfrid Le Gros Clark, is one of the world's leading students of the ancestry of Man, which seems a particularly fortunate circumstance in a place where Man has lived since prehistoric times. A Meeting is infallibly marked by the character of its President's specialisation and thought, but it is tempting to suggest that the influence of the locality itself has had more to do with the interest in early Man and his emergence discernible both in 1935 and 1961. In his Presidential Address to Section H, Dr. K. P. Oakley will deal with dating Man's emergence, and the anthropologists are planning to join with the geologists in discussing Pleistocene dating and Man. The Presidential Address to Section H in 1935 described some recent progress in the study of early Man, while the antiquity of Man in East Anglia was discussed in the Sectional programme. The Association's President that year, Professor W. W. Watts, was a geologist, but his far-reaching survey of the form, drift and rhythm of the continents moves inevitably towards the evolution of man. 'Of all the wonders of the universe of which we have present knowledge . . .' he declared, 'Surely there is nothing to surpass the brain of man. . . . It is indeed the greatest marvel of all.' Another example of the humanising effect of Norwich, perhaps? The man who presided over the Association in 1868, Joseph Hooker, might well have thought so, and it is exciting, reading the old reports, to find him describing as one of the prospects which that Norwich Meeting opened up, a new science that 'has dawned upon us, that of the early history of Man. . . . To search out the whence and whither of his existence,' he concluded his Presidential Address, 'is an unquenchable instinct of the human mind.' Certainly in 1961 it shows no sign of being quenched.

Lecture Service

The month of February 1961 was conspicuous for the number (30) and scope of lectures delivered in connection with the British Association Central Lecture Service.

Sir John Cockcroft, O.M., giving the Radford Mather Memorial Lecture, addressed a large public meeting in Coventry on 'The development of science and technology in the future'. The text of this lecture will appear in a forthcoming issue of *The Advancement of Science*.

Following the pattern of Northern Ireland's annual lectures for schools Professor Dame

Kathleen Lonsdale gave one lecture on 'Crystallography' to 900 schoolchildren in Belfast, and the the next day visited one of the provincial towns, giving the second lecture to 550 boys and girls in Dungannon.

The students of the Architects' Association School of Architecture heard Dr. O. G. Edholm, Head of the M.R.C. Division of Human Physiology, give a fascinating talk on the biological problems of an arctic civilisation, and the Column Group of Shrewsbury, whose particular interest is architecture and the allied arts and sciences, had Professor Kolbuszewski of the Department of Civil Engineering, Birmingham University, to speak to them on 'Form and Function—the use of perspective by architects both for the studies of external form and the purpose of interior decorations'.

'Statistics and the planning of scientific research' was the subject brilliantly presented by Professor G. A. Barnard to sixth formers, technical college students and others at a recent meeting of the Worthing Science Society.

Guildford, Surrey, has recently formed a Guildford Association for the Advancement of Science, with a committee of representatives from many organisations, societies and industries in the district. The inaugural lecture given by Professor H. Bondi was well attended and augurs a lively and progressive programme for the new Society.

By way of celebrating the Golden Jubilee of the School, the Science Society of Harrow County School for Boys had Professor Ritchie Calder to speak to them on 'Fugitives into Space'.

A number of Secondary Modern and Grammar Schools in Lancashire are coming together for a series of lectures arranged by the British Association at the request of the Manchester Federation of Scientific Societies.

The British Association of Chemists in Liverpool provided a large audience to hear Dr. I. G. Campbell of Manchester University speak on nuclear physics.

Manchester Science Fair most Successful

Forty-eight Schools present Seventy-nine Exhibits and attract about 12,000 Visitors.

The 1961 Manchester Science Fair, held at the College of Science and Technology on March 9, 10 and 11, was a great success. That is the opinion of all who saw it.

Organised by the Manchester Federation of Scientific Societies, this was the first fair of its kind to be held in this country. In form it owed much to the Science in Schools Exhibitions which have been a feature of the Young People's Programme at the Annual Meeting of the British Association for some years. This was the first event of the type to be organised 'on its own', apart from the Annual Meeting.

The Manchester Fair had its origin in a visit to the United States by Mr. A. C. Wild, of the Federation of Scientific Societies, early in 1960, at a time when Dr. Watson Davis of Science Service was in England and discussing the possibility of science fairs in this country with the British Association. As the British Association was collaborating with the Federation in the extension of the Federation's lectures for schools in and around Manchester, collaboration over the science fair project was readily agreed. The Association's experience with Science in Schools Exhibitions was made available to the Federation.

In addition, during his visit Dr. Watson Davis had been in touch with Mr. Roy Thomson, Chairman of Thomson Newspapers, Ltd. These discussions were continued, and Thomson Newspapers, Ltd., agreed to provide financial and other assistance for science fairs arranged by the British Association, including that contemplated by the Manchester Federation in which the British Association were collaborating.

The Manchester Federation's plans were completed at the end of October, 1960. The College of Science and Technology had most generously agreed to make the rooms required available without charge, except for labour and service, and the dates had been fixed. It had been thought that schools would require at least two full terms' notice of a fair, and preferably a year's notice, to prepare projects. In fact, they had less than two terms, and in many cases had worked up their projects since January 1961. It was envisaged that financial assistance might be given to schools for basic materials for their exhibits, or for transportation. These small grants did in fact prove invaluable; without them, a number of schools might have been prevented from taking part. Mounting of the exhibits was made easier by the loan of display panels by the education authorities, and by Thomson Newspapers, Ltd.

The Fair was opened on the morning of Thursday, March 9, by the Lord Mayor, Alderman J. Donovan, J.P., who was introduced by Councillor M. P. Pariser, the President of the Federation, and thanked by Mr. D. Avison, the Chairman of the Committee.

When the Fair was opened, a good number of early visitors were already present, and all the first day they swarmed in. After tea, when the organised school parties had left, there was a steady stream of new visitors, including many adults, and the hall was still well attended when the closing hour came at 8 p.m. Some 5000 visitors on the first day were equalled on the second day, with parties from Sheffield, Keighley and many other places outside Manchester. At one time a message was received that a train-load of three hundred visitors was on its way, unannounced, from an unascertained centre. On the Saturday morning the Fair was open for the general public. In all some 12,000 visitors came to the Fair.

Among them were a number of representatives of Area Committees who had come to see the scheme in operation, before considering further whether to organise a fair themselves. These came from Aberdeen, Tay-side, Newcastle, Tees-side, Hull, Sheffield, West Riding, and West Midlands Committees. These were rather special visitors, but certainly impressed—as was the doctor who looked in on his way home, and rushed off full of enthusiasm, to fetch his whole family to see it. 'This must be an annual event,' he said.

There was much to impress. The comparatively short time available for preparation of exhibits was probably partly responsible for the very wide scope covered. Some were mere demonstrations of equipment, such as the Tesla coil (Sale County Grammar School—Boys), the oscilloscope and voice-operated relay (Dulcie Technical High School) and the harmonograph (Altrincham Grammar School—Boys) which was tracing intricate patterns for the whole period of the Fair. On the other hand, there were many projects which had been undertaken in the schools in the normal course of events, without thought of the Fair.

This was certainly the case with the Survey of Baguley, shown by Baguley Hall Secondary School —a most imaginative and surprisingly ambitious social survey which must have been of great value to the children who conducted it. Among the fascinating figures produced were the fact that 12 per cent of the sample of female workers were engaged on the school meals service, and the fact that nearly 40 per cent of male workers are motorised, travelling to work by private transport. There were a number of other very fine group projects, among which it is only possible to mention a few, in alphabetical order:

Alma Park Secondary School. The centre-piece of this 'Investigation of tobacco smoke' was a paper representation of the human chest, cut away to show muscles, ribs and lungs; there were various filtration experiments, and an answer to the question, 'do filter tips make any difference?' Also shown were essays on various stages of the project by Ann Jones, June Singleton, Ann Chagton and Suzanne Chipman.

Barlow Hall County Secondary School. (*a*) Plant Physiology and potting composts—an examination of the effect of fertiliser on radishes, with the result of various concentrations shown in graph form after 16, 19 and 23 days, showing that after 16 days, 10 ozs. per square yard gave the best result, after 19 days, 6 ozs. was best, and after 23 days, 4 ozs. There was also an illustration of osmosis and plasmolysis. (*b*) Extraction and chromatographic separation of proteins in plants. This was based on the British Association symposium on world food and population at Cardiff last September, and while not outstanding in presentation showed how an idea could be worked out.

New Moston Secondary School. Ray track optics, demonstrated with home-made apparatus and great enthusiasm. They couldn't explain why total inside reflection took place in a prism, but never mind.

Newton Heath Technical High School. Four-day survey of Castleton. A very good effort, with a plaster model, pen drawings, and a good deal of careful observation. They had not hesitated, as the beautifully written introduction confessed, to switch aims in the middle of the survey when it became clear that the time factor was against them, and to concentrate on fossils.

North Hulme Secondary School. Built round a very frank photograph of 'Our School' in one of Manchester's less favoured areas, this exhibit of

'A Town School's Garden' showed the benefit obtained from a garden of seven plots some two miles from the school, where every pupil spends at least a half-day each week and learns quite a lot in the process.

North Manchester Grammar School (*Girls*). Soil. A profile of the site of the school, and an illustration of soil formation; examples of chemical and mechanical analysis; animals found in soil; micro-organisms and nitrogen circulation; and water culture experiments.

Sale County Grammar School (*Boys*). Ecological survey of woodland. This is an excellent project in every way, painstakingly conducted, meticulously presented and enlivened with beautiful drawings.

St. Clare's Secondary School. A model house, built from balsa wood and chip-board on a Swedish plan, to illustrate central heating, hot-water and electric lighting and power systems, with model furniture. The aim of this project, which took a month to work up, was to interest both boys and girls.

St. Columba's Secondary School. A demonstration power pack, showing the transference from alternating current to direct current in six stages. This was built by the boys, and is now being used as a teaching aid.

St. Margaret's Secondary School. A study of air pollution, with an effective painting of an old-style manufacturing city as back-ground. The exhibit showed graphs of smoke and sulphur dioxide daily volumes taken from four sites, and deposited atmospheric pollution taken from eight sites. Also shown were weather records, filtration processes and filter pads, and damage to stonework and roofs caused by pollution.

St. Mary's Road Secondary School. Biological study of a city canal. Insalubrious, but made to be educative and fascinating, and presented with style and accuracy.

Smedley Secondary School. The evolution of the steam engine, illustrated by Meccano models and models of various engines and their valves.

Spurley Hey Secondary School. Science round an Austin 7. An ancient 'perambulator', partially dismantled, which had been used to illustrate a number of scientific principles, each of which was set out separately. One interesting fact about this project was that there were more girls than boys who had worked on this lovingly cared-for vintage car.

Walkden County Secondary School (*Girls*). A simple exhibit, showing 'Products from Coal', from which a good deal could be learnt.

Wythenshawe Technical High School (*Girls*). Experiments on fabrics. Six samples of nylon, cotton, wool, silk, rayon and Terylene had been subjected to a number of tests, including various dyes and mordants, boiling, heat, burning, ironing hot and cold, acid, alkali, and fire-proofing.

The results were closely observed and neatly presented by Marilyn Leicester, Jean Mulliner and Marilyn Slater.

There were several geological exhibits, including two of great scope and richness by Sharston Secondary School and Old Moat Secondary School. More modest, but none the worse for that, was the exhibit of Nelson Secondary (Technical) School.

No prizes were offered for exhibits, but each school participating in the Fair will receive a Certificate of Participation.

The enduring impression of the Fair was the sense of fun and excitement in the exhibits and clearly shown by the demonstrators. The days of the Fair were long, and must have been tiring; but the fun and excitement were there right up to the closing hour. This is the best possible justification for this type of event, and for the type of project which found a place in the Fair. Anything which can encourage and preserve the idea that science is exciting and good clean fun is most valuable. The Fair was clearly an inspiration to further effort, and a memorable and stimulating occasion for the demonstrators and many visitors.

THE STANDARDIZATION OF HEARING MEASUREMENT

By T. S. LITTLER *Director, M.R.C. Wernher Research Unit on Deafness.*

In a paper on 'The Peripheral Mechanism of Hearing' published in *The Advancement of Science*, XVII, No. 68, November, 1960, Professor W. Burns gave a very lucid and comprehensive account of the physical and physiological behaviour of the aural mechanism, particularly in the normal state. The ways in which its performance may be affected by abnormalities and disease are in the province of otology, of which the special branch of audiometry is concerned with the derivation of figures which can be taken as the measure of the auditory state.

There are various otoscopic observations which indicate unequivocally the presence of aural disease in the conductive mechanism, but defects in the perceptive and analytical system are located by tests developed by otologists as a result of experience and a rather arbitrary definition of normality, and judgments can only be given when a subject has some difficulty in hearing the quieter sounds of ordinary life. Between the state of normality and that of subjectively observable abnormality there is a definite region of abnormality which can be demonstrated by modern methods of physical measurement.

In setting up physical standards of hearing we make use of a statistical survey of the hearing characteristics of a random population, from which subjects with obvious aural disease can be eliminated although in practice, owing to the low prevalence of such defects, their presence has no appreciable effect on the modal or median value of the physical characteristics representing normality. Such surveys can include different age groups and can give derivations of the ageing effect on normal hearing referred to as presbycusis.

The most important use of human hearing is the reception and interpretation of speech, and at first thought it might be argued that speech would be a logical medium to use for hearing measurement. However, there is a definite relationship between the complex acoustic vibrations of speech sounds and the pure tones or sinusoidal vibrations into which they can be decomposed by what are known as Fourier, Laplace and other transformations. Since from these transforms every speech sound can be considered as made up of a complicated spectrum of pure tones of different intensities it is much more convenient and easier to obtain precise and sensitive measurements of detectability of response by using pure tones in the testing procedure. For measurements of the performance of the ear at sound intensities well above the threshold of detectability, however, we have not as yet reached a stage at which pure tone testing can give as much information as direct measurements of articulation of speech sounds at different intensities, that is, speech audiometry.

When sound is propagated in air, the particle movements or vibrations are associated with a variation of the static atmospheric pressure which is referred to as the sound pressure, and this is the characteristic of a sound field that is representative of the magnitude of the ear's response and its subjective attribute of loudness. In making measurements of sound fields, we can express the sound pressure directly in dynes per square centimetre or, for convenience, as the number of decibels above or below a standard sound pressure, which has been arbitrarily chosen as a sound pressure of 0·0002 dyn/cm^2, and the decibel magnitude is then designated the 'sound pressure level' (S.P.L.). A sound pressure of 1 dyn/cm^2 is 74 dB S.P.L. on this scale, so that when intensities are given in dB above 1 dyn/cm^2 the figure of 74 can be added to convert to S.P.L.

In the assessment of normal hearing where the aim is to determine the sound pressure level at which pure tones are just audible, it is very important that the testing procedure shall be clearly defined and this requirement follows for any other survey, such as an epidemiological or industrial one, where the hearing of personnel is to be compared with normality. When a pure tone is suddenly applied to the ear, there is first a transient state, heard as a click, and the sensation of a definite pitch does not occur until the sound has been applied for an appreciable period, which varies from about one-hundredth of a second for frequencies of 500 to 5000 c/s to about one-twentieth of a second for a frequency of 50 c/s as shown in Fig. 1. The pitch after these critical periods is not

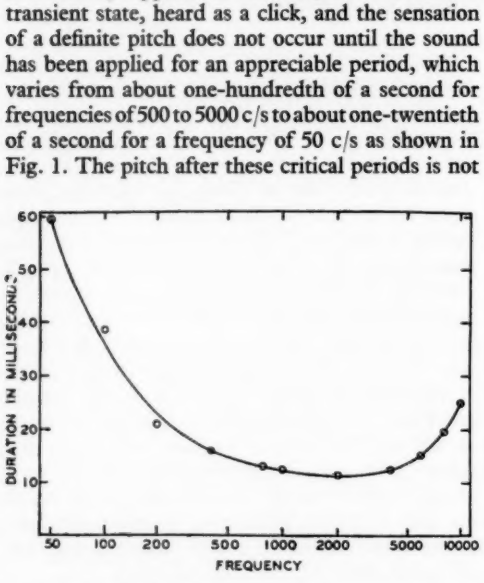


Fig. 1.—Showing how long a tone of a given frequency must last in order to produce the experience of a definite pitch. (*After Bürck, Kotowski and Lichte.*)

very definite, but appears to become higher as the duration is increased up to a stabilisation time (about 0·03 sec. for 1000 c/s) as shown in Fig. 2. Another important characteristic is that the pulse appears to become louder as the duration is increased, for example the effective intensity of a 100 c/s tone increases by about 20 dB when the duration is increased from 1 to 50 millisec. and a duration of about 0·5 to 1 sec. is required before the loudness reaches it maximum. At the cessation of the pulse, transient effects again appear as would be expected when it is realised that the termination of a pulse is equivalent to the injection of an equal but phase-reversed pulse. To avoid

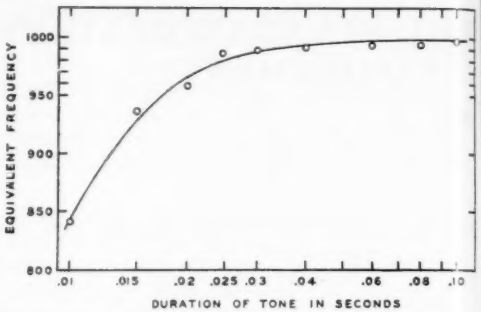


Fig. 2.—Showing how the pitch of a tone changes as a function of its duration. The ordinate shows at what frequency a tone lasting 1·5 sec. sounds equal in pitch to a 1000-cycle tone presented for the period of time indicated by the abscissa. Example: a tone of 1000 cycles lasting 0·01 sec. sounds equal in pitch to a tone of 842 cycles lasting 1·5 sec. Each point represents the average of 60 observations by a single observer. (*Ekdahl and Stevens.*)

transient effects it is necessary to ensure that the onset and decays of the tone stimuli are gradual, and to eliminate errors due to duration of pulses it is essential that the steady portion of the pulse has a duration of at least a second. American and British standards for pure tone audiometers specify limits for the build-up times of their tone pulses. In the British specification (British Standard 1958) the requirements are stated as follows:

When the interrupter switch is moved to the ON position the time taken for the output voltage operating the earphone to attain the fraction 0·9 of its steady value shall not exceed 0·5 sec. from the instant of operating the switch. The time taken for the voltage to rise from 0·1 to 0·9 of its final steady value shall not be less than 0·5 sec.

Similar conditions are specified for the decay times. These maximum and minimum values have been set to take into account as much information as was available at that time regarding the audibility of transients and the practicability of incorporating them in commercial instruments. Recent investigations by Wright (1958, 1960) suggest that the prescribed times are unnecessarily conservative and that the minimum rise and decay times might be of the order of 5 millisec. instead of the 500 millisec. specified. However, the particular switching time associated with a given audiometer, whatever it happens to be, must be taken into account in

specifying the minimum duration required for a signal when the minimum threshold is to be assessed. Considering the present values of commercial audiometers it seems therefore that a duration of at least 1 sec., and preferably 2 sec., should be used if meaningful results are to be obtained from pure tone audiometry.

In the most accurate investigations of the threshold of audibility, electro-acoustical methods of measurement have been used both for generating the stimulating sound, and for determinations of the associated sound pressure. Some of the measurements have been direct measurements of the acoustic pressure at the entrance to the meatus or at the eardrum, and some have been measurements of the pressure at a region in a free field before the listener's head is in position. In the most convenient methods the sound has been delivered to an earphone and the actuating voltage at the earphone at the threshold has been used for reference purposes, although the equivalent pressure at the meatal entry or eardrum may have been determined at the same time as the voltage measurements. When the threshold is given in terms of the pressure at some point in the external ear, it is referred to as the *minimum audible pressure*; when it is given in terms of the unrestricted free field pressure before listening has taken place without a telephone on the ear, it is referred to as the *minimum audible field*.

The first intensive studies of hearing of large groups of people were made by Fletcher and Wegel of the Bell Telephone Laboratories in 1922, who used their information in the design of pure-tone audiometers, planned to deliver at the ears of listeners sound pressure levels which were specified dB above levels representative of normal hearing. About that time, and during the next ten years or so, a number of other independent investigations took place and, in 1933, Sivian and White reviewed the whole research up to that time and published what they considered were the best weighted means. Their results are shown in Fig. 3. It can be seen that the minimum audible field curve is consistently below that of the minimum audible pressure. Later research has shown that most of this difference can be explained on account of diffraction of the body producing a greater pressure at the entry to the meatus than there was in the unobstructed free field, resonance in the meatus enhancing the pressure at the eardrum and the masking of physiological noise when the ear is closed by an earphone.

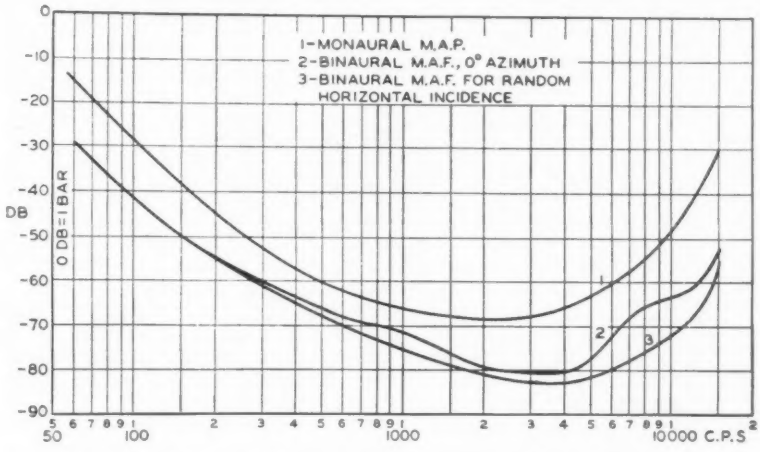


Fig. 3.—Thresholds of hearing for pure tones, assessments for minimum audible field and minimum audible pressure by Sivian and White (1933).

In recent years, a series of audiometric surveys have taken place at World's Fairs in the United States from which median values for the threshold

of audibility some 10 dB or so higher than the Sivian and White data were obtained, and on these data the American Standards Association (1951) proceeded to issue a standard of normal hearing known as the American Standard. Much doubt has been thrown on whether this was a justified action in view of the conditions of World's Fairs, and also as tests using audiometers based on their results gave what could be classed as optimistic values of hearing acuity. In the United Kingdom, a new investigation on the threshold of audibility for young normal listeners (ages 18–25) was undertaken by Dadson and King, of the National Physical Laboratory, from 1946 onwards at the instigation of the Electro-acoustics Committee of the Medical Research Council. Their results were very close indeed to the Sivian and White assessment and were confirmed in 1952 by Wheeler and Dickson of the Central Medical Establishment of the Royal Air Force. These results formed the basis of the British Standard of normal hearing issued in 1954. Figure 4 gives the results of these more recent determinations together with Sivian and White's assessments. Surveys carried out jointly during 1958 and 1959 by the Pneumoconiosis Research Unit and the Wernher Research Unit of the Medical Research Council amongst rural communities in Glamorgan and Dumfriesshire, have shown that a carefully controlled survey using a standardised technique, referred to later, gives values for a modal threshold indistinguishable from the British Standard. Arising out of these surveys, Hinchcliffe (1959) has determined presbycutic curves for random rural populations over the age groups 18 to 74 (Fig. 5). In the meantime, as a result of further investigation and exchange of data between workers in Europe and the United States there is a consensus of opinion tending to favour the acceptance of a standard nearer to the British than the American, and the adoption of an international standard of this order is probably not far off.

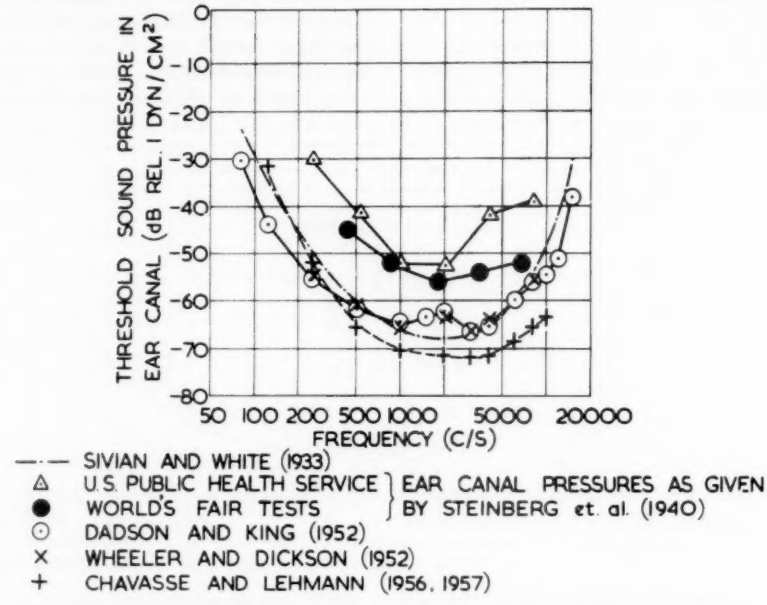


Fig. 4.—Minimum audible pressure at the entrance to the external auditory meatus according to various investigations. The results of Dadson and King and Wheeler and Dickson are the basis of the British Standard. (*Reprinted with permission from Robinson and Dadson* (1957).)

Although at present the two standards differ, each is reproducible objectively by means of an artificial ear or coupling device. The function of this device is to provide a means of comparing objectively the response characteristics of an earphone under test with those of a reference earphone of the same type, the performance of the latter having been evaluated on human ears by appropriate measurement and subjective tests. It has approximately the same volume and acoustical impedance as an average real ear and is provided with a microphone device for measuring the actual sound pressure when the earphone applied to it is actuated by an alternating voltage of known value. It is the subject of standardisation in various countries.

The existence of different standards of normality, therefore, does not interfere with the accuracy with which a measurement of hearing can be made, since all threshold measurements can be converted to equivalent pressure at the entry to the meatus or in a specified artificial ear. The hearing acuity of an individual can be compared with that of normality of an agreed standard by means of an audiometer designed to that particular standard. Such an instrument has an attenuator adjustment usually in 5 dB steps and by means of an interrupter switch it is possible to apply signals of any desired duration and appropriate intermittency. The difference in decibels between the threshold of hearing of the person being tested and the standardised norm is known as his hearing loss. The technique of testing should preferably be the one similar to that used for setting up the standard of normality, but so far independent workers have differed in their methods somewhat, although it is probable that even this aspect of audiometry will become standardised ultimately. The response to signals near to the threshold of hearing when applied at constant intensity is not a simple 'yes' or

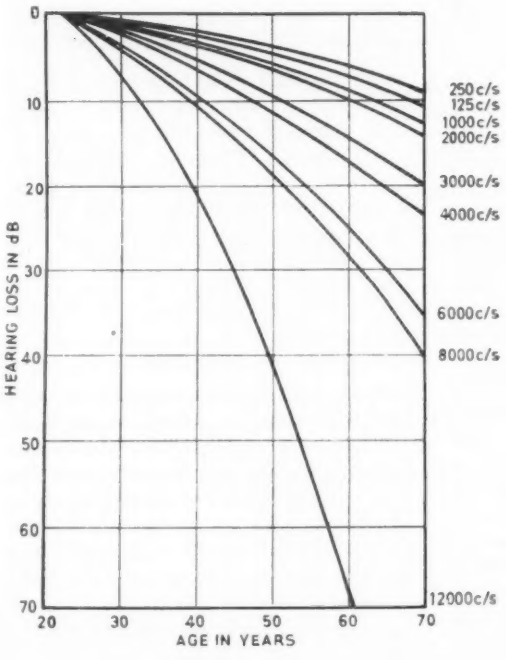


Fig. 5.—Smoothed presbycusis curves derived from the data of a random sample population. The curve for 500 c/s has been omitted to avoid overcrowding; it lies between the curves for 125 c/s and 250 c/s. The curves are equally applicable to men and women up to the age of 54 years and for frequencies up to 2,000 c/s. Above this age and frequency the curves refer to women. (*After Hinchcliffe, R., 1958, and by courtesy of the Editor of 'Gerontologia'.*)

'no' response but shows a statistical relationship illustrated by the sigmoid curve shown in Fig. 6. If the signal is sufficiently intense the subject will

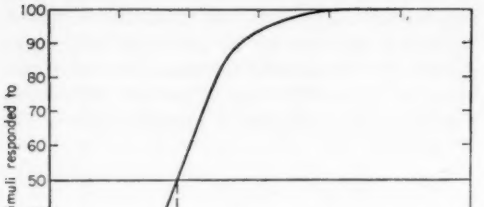


Fig. 6.—Idealised sigmoid curve representing statistical results of responses to pulses of pure tone. (*After Hirsh (1952.)*)

respond to it every time it is applied to the ear, but for every subject there is a broadly defined level below which he begins to experience difficulty in feeling certain that he has heard it, and further reduction of the intensity results in a rapid decline in the percentage of signals responded to. This curve shows hysteresis characteristics and the sigmoid for increasing intensity is displaced to the right of that for decreasing intensities. A suitable criterion of acceptable threshold is that giving a 50 per cent response, and this point being on the steep portion of the sigmoid curve is very sensitive to intensity change. Of course, the limited time that can be given to an audiometric measurement prohibits the use of a large number of signals of constant stimuli, but it has been found in practice that the criterion of at least a two out of four response has given satisfactory and reproducible results. The recommended procedure is therefore the application of stimuli at some level judged to be above the subject's threshold to which he is asked to respond by some visual acknowledgement, such as pressing a button which switches on a light signal. The threshold is then approached by the method of limits to assess the descending value, using the two out of four criterion as the threshold is reached. Then the threshold is again approached at ascending intensities. Owing to the narrowness of the hysteresis curve and the 5 dB steps usual in audiometry, the ascending and descending thresholds are identical in the majority of instances but if they differ their mean is accepted as the threshold.

Standardization of Audiometer Instruments

The fundamental features of audiometers are now the subject of standardisation by most national standardising bodies. In addition to the onset and decay time requirements, these include:

(1) the range of test tones, at least 250 c/s to 8000 c/s being required;
(2) purity of output sound;
(3) standard of normal hearing which preferably is indicated on the instrument;
(4) type of earphone to be used. This should be of a type that maintains its calibration over long periods and should be free from pronounced resonances;
(5) effect and avoidance of different noise disturbances;
(6) method of calibration.

Where the highest accuracy of measurement is required, and particularly in hearing surveys aimed at observing slight departures from the normalities observed in rural populations, it is very important that the performance of the audiometer should be checked frequently. Ideally the acoustical output of the earphone should be determined by means of its response on an artificial ear, but this is a laboratory procedure; in practice it is sufficient to monitor the electrical voltage actuating the earphone at some convenient times daily, with the artificial ear calibration brought into operation at less frequent intervals. These precautions can be supplemented by frequent subjective tests of the operator on his own ear. A fuller discussion on methodology of pure tone testing has been discussed in more detail elsewhere (Hinchcliffe and Littler, 1958).

Hearing by Bone Conduction

Although not an important contribution to normal hearing, a certain fraction of applied sound energy reaches the cochlea through its bony

structure and surround. However, when the conductive mechanism becomes impaired there is a reduction of hearing by air conduction without a corresponding reduction by bone, and therefore the assessment of hearing by bone conduction in association with that by air can be useful in diagnosis. This is particularly useful in eliminating instances of conductive deafness from surveys of possible deafness due to industrial noise, where evidence of conductive deafness can be considered as an indication of absolution of noise as its cause. Unfortunately, standardisation of bone conduction hearing has not reached the stage of precision achieved for air conduction and devices for objective calibration of bone conduction transducers, known as artificial mastoids, are still in a slow course of development; consequently, bone conduction audiometry has to rely on subjective calibration of the actuating voltage on the transducer to give normal threshold. The occlusion effect, i.e. the phenomenon of enhanced hearing by bone when the ear is occluded by a plug or the finger tip, can generally be considered as indicating freedom from conductive impairment.

In using the audiometer as an aid to diagnosis the so-called air/bone gap, that is the difference in the hearing loss as registered by air and bone conduction, is an indication of conductive loss. There are other tests involving localisation of sound transmitted by bone conduction which can be used to supplement information obtained from the threshold tests.

Hearing Conservation

Hearing conservation programmes in industry aim at the protection of personnel against the acquisition of industrial deafness, particularly the more susceptible, and they are very simple. A clinical examination of the ears together with audiometry is made at the commencement or prior to employment and thereafter audiometry is performed at appropriate, say six-monthly, intervals. If clear signs of deterioration with regard to the initial audiogram are obvious, conservative steps can be taken before damage is significant. In this way both the employee and employer are protected.

Speech Audiometry

As mentioned earlier, for measuring the response of the ear at supra-threshold intensities speech is more satisfactory than pure tones and the instrument used is the speech audiometer. This is a device for reproducing speech material at known intensities for the purpose of making tests of articulation or intelligibility. Since the component syllables of speech sounds have a range of intensity of nearly 30 dB and a wide variation of intrinsic difficulty of interpretation, it is a matter of careful design to produce lists of syllables, words or sentences for specific purposes.

Just as in other audiometric equipment, it is important to standardize the speech audiometer so that a curve of articulation against intensity is available which represents normal average response. This is accomplished by using a group of young normal subjects as a testing crew. We can then plot the curve of articulation against intensity for a deafened individual, and define hearing loss for speech as the ratio of intensities in decibels for the deafened and normal subject to attain some prescribed articulation score. In laboratory work where testing teams can be conditioned to achieve a maximum efficiency, the ideal speech sounds are considered to be meaningless syllables, but in tests of hearing loss for speech where subjects can only be expected to give a limited time for tests it is customary to use phonetically balanced (PB) word lists, spondee word lists, lists of sentences, or words at the end of carrier sentences. These lists are important components of speech audiometry.

Figure 7 gives examples of the type of speech audiograms obtained for a normal and two deaf subjects in which PB word lists are used. The abscissa gives the average sound pressure levels of the speech sounds, and the percentage words repeated correctly are plotted as ordinates. The normal curves would be of different slopes if sentences or spondee lists were used. A word articulation score of about 50 per cent is almost equivalent to a sentence articulation score of about 80 per cent, and so the level at which a word score of 50 per cent can be obtained can be considered as a critical level for the individual concerned; also the 50 per cent score is usually obtained on some part of the straight portion of the speech audiogram, which is the most satisfactory region for making estimates of the probable form of the curve. We can call the difference in decibels between the levels at which a deaf and normal person obtain 50 per cent articulation scores, the

hearing loss for speech. In Fig. 7(a) the hearing loss for speech is 54 dB for curve (1) and 34 dB for curve (3). Fig. 7(a) is the type of response obtained by a patient with purely conductive deafness, and Fig. 7(b) gives those obtained by patients having perceptive deafness; some perceptive patients cannot obtain very high scores if the cochlea is seriously damaged by deafening reduce the maximum possible articulation. To understand this, it is of value to examine the factors involved in speech recognition. In average conversational speech the maximum acoustic pressure at the ears is attained by the loudest vowels and is of the order of 70 dB S.P.L. The weakest consonants such as *f*, *v* and *th* only reach a level of about 40 dB. Thus, if speech is applied

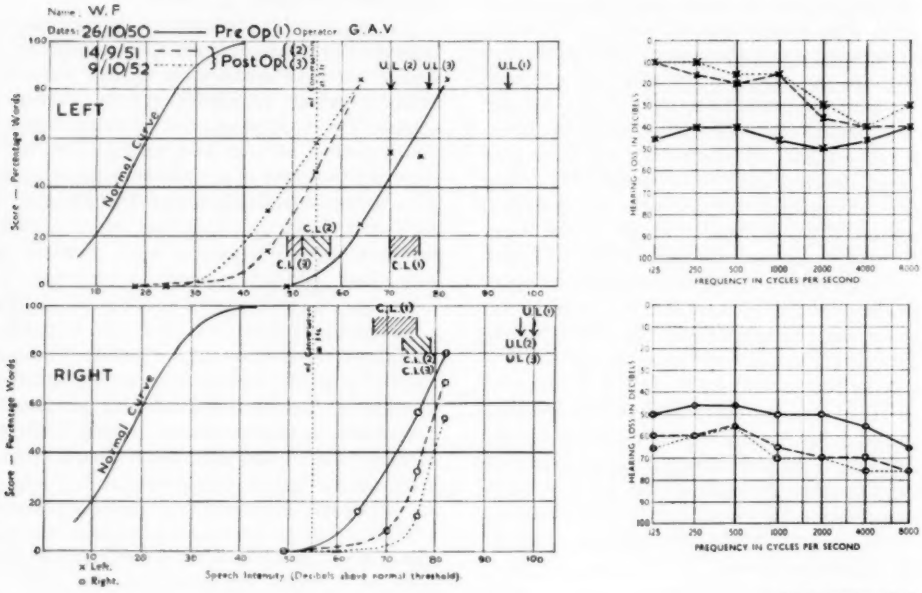


Fig. 7 (*a*)

Fig. 7.—Speech audiograms. (*a*) Patient with conductive deafness. (*b*) Patients with perceptive deafness. The different curves on each speech audiogram show results during the course of operational treatment.
C.L. — comfortable level
U.L. — upper limit of tolerance

disease. Alongside the speech audiograms the pure-tone audiograms are given. As would be expected, the patient with a severe loss to high frequencies is unable to hear all sounds perfectly.

The characteristic shape of the speech audiograms of patients with severe perceptive deafness is probably due to several factors. In such cases we usually have the effects of recruitment of loudness and high frequency deafness contributing to at a comfortable level for the perceptively deaf subject it is probable that the weaker sounds are abnormally low in intensity and not interpreted easily. If the speech level is raised so that the weaker sounds are at their optimum level the louder sounds will be abnormally loud and they will tend to confuse the weaker consonants. Now, in addition, severe perceptive deafness is often associated with larger hearing losses for high

frequencies and, as we know from Bell Telephone Laboratory and other studies, attenuation of high frequency components of speech produces serious loss of articulation, particularly for consonant sounds which contain a great deal of the intelligence of speech. It also happens that some of the consonants that are rich in high frequencies are also quieter as well.

(1) the ability to locate the directions of sound sources due to time differences of arrival at the two ears as well as due to intensity and quality differences of the sound at the two ears, and (2) the ability to discriminate wanted sounds against unwanted noises. Whereas a single ear can only differentiate time differences between pulses of the order of one-twentieth of a second the binaural

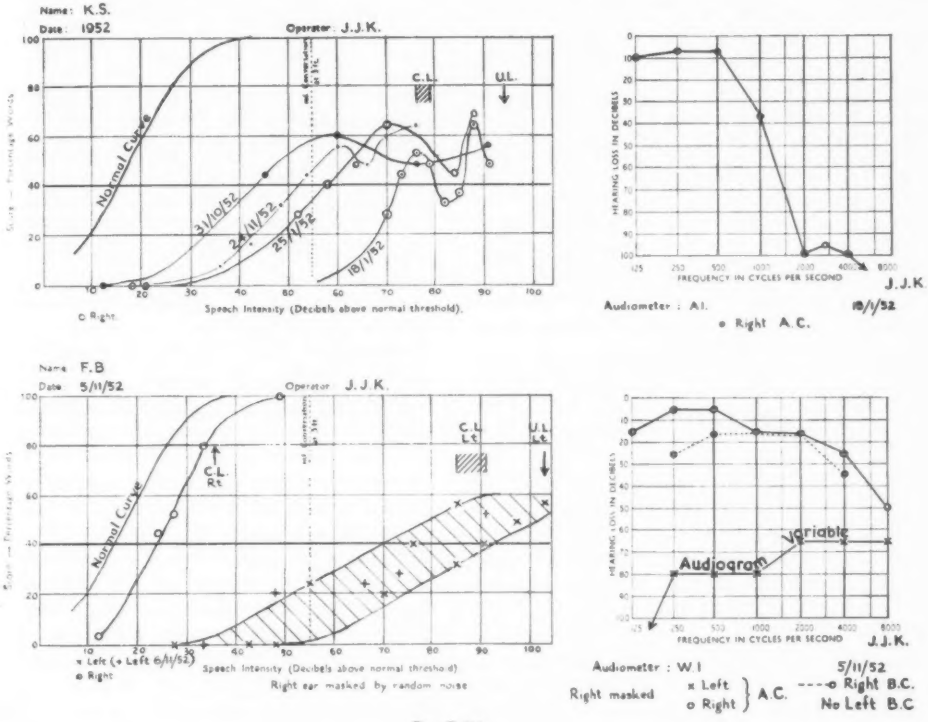


Fig. 7 (*b*)

Binaural Hearing

In normal hearing the sound stimuli at the two ears are transmitted independently along the two halves of the neural pathway to the two separate auditory cortices. The communication from each ear to the specific cortex traverses a series of 4 synapses, but at each synapse there are co-lateral fibres communicating between the two respective halves of the pathway. This two-channel communication system is responsible for the remarkable abilities associated with binaural hearing which are faculty permits a differentiation of a few microsec. Another property of binaural hearing, though apparently not so important as the other properties referred to above, is that the binaural threshold is lower than the monaural threshold by about 3 dB (Chocolle, 1954), and this is shown by the displacements between the sigmoid curves for one and two ears. There are many references to work on binaural hearing in the literature of acoustics, and an excellent summarised account of the subjective effects associated with it has been given by Koenig

the Royal Ordnance Factories at Hirwaun, near Aberdare, and Bridgend and the war factory at Fforestfach, near Swansea, to Industrial Estates. Later, many factories were built throughout the Area for lease or sale to private industry. During this same phase the transformation of the traditional tinplate industry of the Area was started by developments at Trostre, near Llanelly, Velindre, near Morriston, Port Talbot and Ebbw Vale, and the modernisation of the coal industry planned.

Between 1947 and 1949, 179 new factories and factory extensions over 5000 sq. ft. in area were completed, of which 112 were government-sponsored, but activity then decreased rapidly until in 1953 only 8 government and 36 private schemes were completed. By 1952 the original impetus from the Distribution of Industry Act had lessened and a new industrial structure had been created. Thereafter industrial development was confined chiefly to the private sector.

In 1958, government policies were again changing, first with the Distribution of Industry (Industrial Finance) Act, which gave power to give financial aid to industrial and commercial concerns that would reduce unemployment in areas where persistent unemployment existed, or was anticipated, whether or not they were in a Development Area; and then with the Local Employment Act of 1960. This latter Act has, in effect, replaced a comprehensive Development Area policy, which could take note of the interrelationships of an industrial region, by *ad hoc* and uncoordinated expedients, because it is confined to Development Districts, that is, districts where, in the opinion of the Board of Trade, a high rate of unemployment exists, or is anticipated and is likely to persist, whether seasonally or generally.

The period 1952 to 1958 is thus very suitable for a discussion of the consequences of Development Area policy and an examination of the industrial pattern created, but the value of this choice of dates is heightened by statistical reasons. The South Wales Development Area contains within its boundaries over fifty separate employment exchanges. From 1952 onwards, a consolidated set of employment figures for the Area is available, divided into the groupings of the 1952 Standard Industrial Classification, but it has proved impossible to get comparable sets of figures for earlier years. This is because after 1952 the consolidated figures have been adjusted to include people who work in the Development Area but whose insurance cards are held outside the Area, mainly in London. These people, who are not included in the returns from individual exchanges, amounted in 1958 to 5 per cent of the total employment in the Area. They were nearly all agricultural, transport and government workers and there were almost no industrial workers. Finally, the basis of the Standard Industrial Classification was changed after 1958, making comparisons between 1959 and earlier years impossible.

The reason for development area policy was the extremely high, persistent and localised unemployment in the older industrial regions of the country before the war. This, quite rightly, was recognised as being the result of an unbalanced economy in these areas, and a secular decline in their dominant industries.

In 1952 the outstanding characteristic of the industrial employment structure of the South Wales Development Area was still the dominance of the traditional coal and metal manufacturing industries and the comparatively even distribution of employment among the other industrial groups (see Table 1). Between 1952 and 1958, as the effects of the development area policies were felt, the importance of these traditional industries declined, their share of total industrial employment falling from 33 to 29 per cent. Calculation of the location quotients* for the various industries shows the disproportionate presence in the Area of the coal, tinplate and metal manufacturing

* The Location Quotient measures the degree to which an industry is localised in an area. It is calculated by dividing the percentage of total employment in an area in a given industry by the percentage of total employment in the United Kingdom in that industry. If the Location Quotient is greater than 1·0 then the industry is localised in the area, that is, it is more important in the area than in the country as a whole; if less than 1·0, the industry is less important in the area than in the country.

Example: Percentage of total employment in the United Kingdom employed in metal manufacture in 1958 — 2·59 per cent.
Percentage of total employment in South Wales Development Area employed in metal manufacture in 1958 — 10·33 per cent.
Therefore Location Quotient is $\frac{10 \cdot 33}{2 \cdot 59}$, i.e. 3·99.

industries, but whereas tinplate and coal have become less important over the period, metal manufactures have increased in importance.

These quotients demonstrate the lack of industrial diversity in the Area compared with that in the United Kingdom. Further analysis can be made using the concept of growth which suggests that the important factor is the potentiality of an industrial structure for further growth in employment or the avoidance of a fall in employment. It has been possible, by considering the mean national rates of change of different industries given by the Indices of Industrial Production published in the Annual Abstract of Statistics, to classify individual industries according to whether they are expanding or contracting in relation to the mean national rate of change in total industrial production. A graph of the movements in the index of annual production for each industrial group in the 1952 Standard Industrial Classification, which was the best measure available of the changing importance in the economy of the United Kingdom of the separate industrial groups, was drawn for the years 1948 to 1957. Short-term variations were removed by moving averages and post-war trends in production in the various industries were obtained. These graphs were placed in five groups according to their relation to the trend of total industrial production. The first group was the 'growth' industries, those whose rate of increase in production was markedly higher than that for total industrial production. The second group was the 'average' industries, expanding very similarly to total industrial production. The 'slow–steady' group was also expanding at a regular rate but less than that for the total. The 'slow–irregular' group showed some increase in production over the period but their rate of increase fluctuated considerably. Finally, the 'declining' industries, as their name implies, actually showed a fall in industrial

TABLE 1

EMPLOYMENT STRUCTURE IN THE SOUTH WALES DEVELOPMENT AREA

Standard Industrial Classification: 1952 edition	*Percentage* 1952	1958	*Location Quotient* 1952	1958
GROWTH INDUSTRIES	12·39	12·69	0·64	0·62
Chemicals and allied trades	2·35	2·44	1·00	1·01
Engineering, shipbuilding and electrical	5·45	5·84	0·51	0·59
Vehicles	3·66	3·32	0·71	0·60
Paper and printing	0·93	1·09	0·38	0·41
AVERAGE INDUSTRIES	13·10	12·34	2·49	2·37
Metal manufactures	11·04	10·33	4·17	3·99
Wood and cork	0·87	0·67	0·62	0·51
Other manufactures	1·19	1·34	0·99	1·02
SLOW–STEADY INDUSTRIES	5·12	4·60	0·71	0·65
Clothing	2·31	1·83	0·74	0·63
Food, drink and tobacco	2·81	2·77	0·70	0·66
SLOW–IRREGULAR INDUSTRIES	5·72	5·96	0·61	0·68
Treatment of non-metal mining products	1·30	1·13	0·80	0·75
Other metal goods	2·81	2·82	1·17	1·22
Precision instruments	0·58	0·70	0·92	1·03
Textiles	1·03	1·31	0·22	0·31
DECLINING INDUSTRIES	18·34	16·24	4·11	3·90
Mining and quarrying	18·15	16·06	4·37	4·13
Leather and leather goods	0·19	0·18	0·58	0·62
Total, industry	54·67	51·85		
Total, service and agriculture	45·33	48·15		
Total	100·00	100·00		

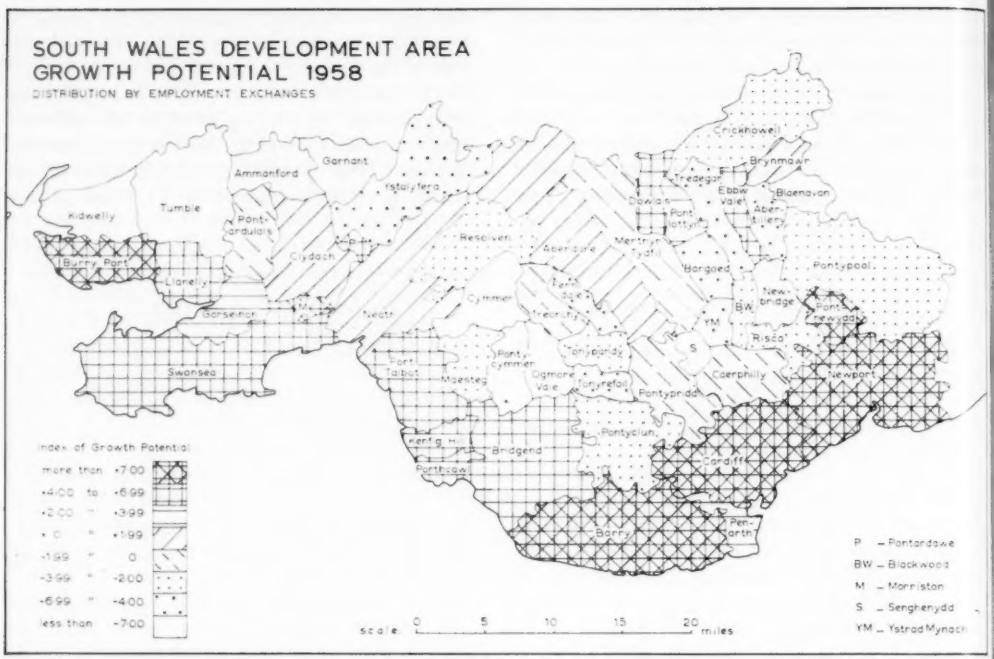


Fig. 1

production between 1948 and 1957. The division of the industries between these five groups, and their location quotients, is shown in the table.

A picture of the potential strength of the Area's industrial economy is thereby given. The highly localised industries belong to the declining and the average groups, while the growth, slow–steady and slow–irregular groups are not localised, although neither are they conspicuously absent. However, only the slow–irregular group is increasing in local importance. The most noticeable feature of the industrial economy of South Wales is the absence of growth industries and the continuing, though decreasing importance of the declining industries, which suggests that on this criterion at least, the industrial structure of the area is still lacking a potentiality for expansion, a fact supported by the failure of industrial employment to increase during the 1950's. Whereas nationally, industrial employment increased by 5 per cent over the period, in the Development Area it remained fairly constant, in effect relatively decreasing.

Because the period 1952–8 has thus shown little overall change and because 1958 is the end of a period both administratively and statistically, it is proposed to limit the discussion of the pattern of employment created within the Development Area to that year. The industrial economy will be discussed in terms of growth potential, the proportion of employment in manufacturing industry provided by government action, unemployment and diversity, and it will be suggested that growth potential is the most illuminating attribute.

The first map (see Fig. 1) shows the index of growth potential for each employment exchange. It was derived by using location quotients to measure the concentration of each of the five groups of industries in each exchange by comparison with their importance in the Development Area. The Location Quotients were then weighted according to the economic growth potential of each of the groups. It was assumed that a presence of growth industries and an absence of declining industries were of equal significance for economic strength. Thus the weights used were +3 for growth, +2 for average, + 1 for steady, −1 for

irregular and —3 for declining. After weighting, the five quotients for an exchange were added together and the result called the Index of Growth Potential.* An index of +7 or more indicates an industrial structure with considerable possibilities of further extension or the avoidance of secular decline because of the importance in it of those industries which are nationally expanding. An index of −7 or less implies the opposite: nationally declining industries are highly localised, nationally expanding industries are missing; such an area will probably decline in relation to the rest of South Wales.

The strength and weaknesses of the Development Area are thus clearly shown. The eastern coastal fringe from Barry to Newport, including the new town of Cwmbran near Pontnewydd, is uniformly strong while the western coastal fringe around Swansea Bay and the Loughor Estuary is slightly less so. Inland, with the exception of Ebbw Vale, Pontardawe and, marginally, Dowlais, the whole area is weak in growth potential. In more detail, the worst areas are the Monmouthshire Valleys, except Ebbw Vale, the middle Rhymney Valley and Senghenydd, the Rhondda and upper Ely, the Ogmore and Garw Valleys and the western margins of the coalfield in the Amman and Gwendraeth Valleys.

A comparison may be made between these areas of growth potential and the distribution of government-aided industry. This map (see Fig. 2) shows an estimate of the employment given by the various government schemes mentioned in the annual Reports on Government Action in Wales and Monmouthshire. It includes employment in all the factories controlled by Wales and Monmouthshire Industrial Estates Limited, war factories allocated

* *Example*: Cardiff Employment Exchange, 1958—

	Location Quotient	*Weighting*	*Result*
Growth industries .	1·63	+3	4·89
Average industries .	1·20	+2	2·40
Slow–steady industries .	2·10	+1	2·10
Slow–irregular industries .	0·97	−1	−0·97
Declining industries .	0·07	−3	−0·21
Therefore Index of Growth Potential			8·21

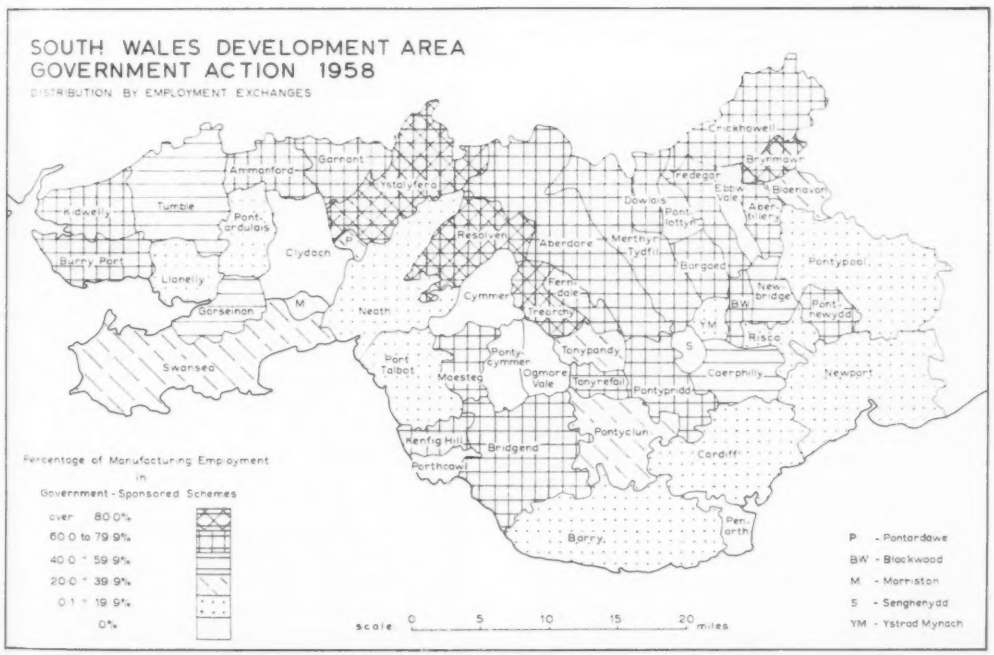


Fig. 2

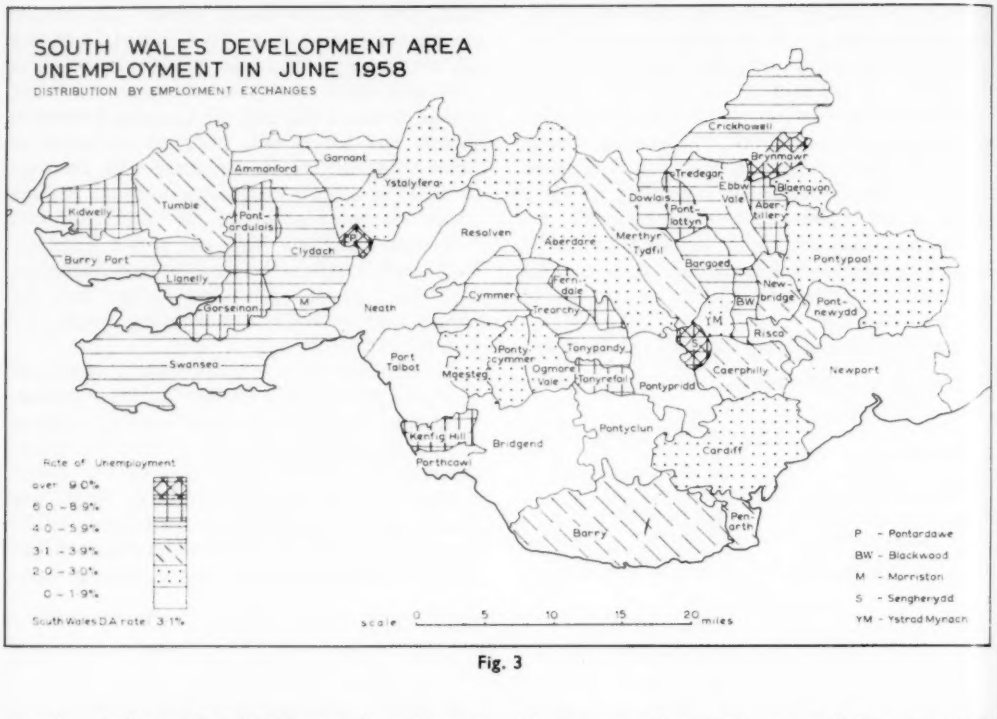


Fig. 3

to private industry, Royal Ordnance Factories and Remploy factories. It excludes developments in coal, iron, steel and tinplate as they were not directed at the problem of a lack of diversity.

The most significant features of this map are (*a*) the concentration of government projects on the coalfield and the very high proportion of manufacturing industry in these areas given by such schemes; (*b*) the absence of government activity from the coastal areas, the Ogmore and Garw Valleys, from Ebbw Vale and the areas immediately behind Swansea and Newport; (*c*) generally speaking, the areas of high growth potential have a small proportion of government-induced industry—Llanelly, Port Talbot, Porthcawl, Barry, Cardiff, Newport and Ebbw Vale; while in Swansea, Gorseinon, Morriston and Pontardawe at least 40 per cent of manufacturing employment is private. Only Burry Port and Pontnewydd show both a high growth potential and much government initiative, and in both these areas there are exceptional circumstances. Burry Port has only one large factory, an ordnance factory, and Pontnewydd is the exchange for Cwmbran New Town; (*d*) the converse is equally true; except for the Ogmore and Garw Valleys which have received virtually no government aid but which are within easy reach of the large industrial estate at Bridgend, the areas with a high proportion of their manufacturing employment in government-sponsored works, that is above 60 per cent, have a low growth potential.

The next map (see Fig. 3) shows the 1958 rates of unemployment. These figures are for all unemployment in the insured population as it was impossible to obtain more detailed statistics. In 1958 the average unemployment rate for South Wales was 3·09 per cent, while the range of values extended from under 1 per cent to over 10 per cent. It seems from this map that there is no correlation between unemployment and the degree of government aid. Thus the three areas with the highest unemployment rates have, respectively, 81, 21 and 0 per cent of their manufacturing employment in government-aided works. Generally,

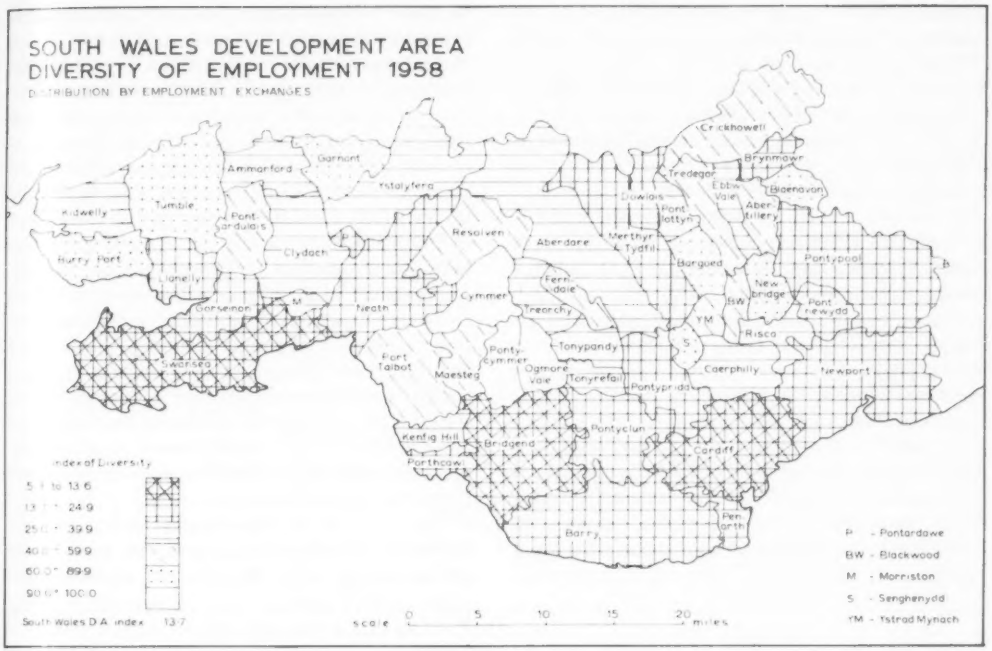


Fig. 4

areas with high growth potentials have low unemployment, but there are exceptions in the west around Swansea and Llanelly. This is the area where steel and tinplate are very important. They are industries with average growth potential so these areas will show fairly good growth indices, but they are undergoing extensive reorganisation and the consequent dislocation is causing local unemployment.

Turning now to diversity, an index capable of making comparisons between different degrees of diversity has been devised. By taking the industrial structure in percentage form, squaring the percentage in each industrial group, adding the squares and dividing by 100, an index is obtained that gives, in this instance, theoretical maximum and minimum values of 100 and 5·3. Thus, for example, if all employment is concentrated in one industry and the area is completely undiversified, the index will stand at 100, obtained by squaring 100 per cent and dividing by 100. The theoretical maximum diversity would occur if all industries shared the total equally. There are nineteen industrial groups and the individual percentage is therefore 5·3; this, squared for each industrial group, totalled, and divided by 100, gives a value of 5·3 *

* *Example*: Maesteg Employment Exchange, 1958—

	%	(%²)
Coal mining	67·5	4556·25
Other mining and quarrying	0	0
Treatment of non-metal mining products	0·5	0·25
Chemicals and allied trades	10·7	114·49
Sheets and tinplates	0	0
Engineering	3·5	12·25
Shipbuilding	0	0
Electrical goods	0	0
Vehicles	0·7	0·49
Other metal goods	0	0
Precision instruments	0	0
Textiles	0	0
Leather goods	0	0
Clothing	7·2	51·84
Food, drink and tobacco	1·2	1·44
Wood and cork	0	0
Paper and printing	8·2	67·24
Other manufactures	0	0
Total	100·0	4804·50

Therefore Index of Diversity $= \frac{4804 \cdot 50}{100} = 48 \cdot 0.$

Areas shown by the map (see Fig. 4) to be extremely undiverse—the Ogmore and Garw Valleys, the remoter parts of the anthracite area, and certain parts of the Monmouthshire Valleys —have a low growth potential. On the other hand, though there is some degree of correlation between high growth potential and a diverse structure, for instance, in the coastal areas, there are exceptions and, therefore, neither a high nor a low amount of diversity is a reliable criterion for industrial prosperity. For example, Brynmawr is fairly diverse but has a low growth potential, a high rate of unemployment and much government-sponsored industry. Port Talbot is fairly undiverse but has a high growth potential with almost no unemployment and a negligible amount of government induced industry.

It is now possible to return to the map of growth potential (Fig. 1) and, in the light of refinements suggested by the consideration of the maps of diversity, unemployment and government action, to divide the Development Area into areas of varying growth potential. The fundamental division is two-fold, as was hinted at in the beginning of this paper (see Fig. 5). The coastal fringe of South Wales from Llanelly in the west to Newport in the east may be contrasted with the mining valleys. The coastal fringe is the area of high growth potential and, in general, a relatively diverse industrial structure, and it may be sub-divided into an eastern and a western sector. The eastern includes Barry, Cardiff, Newport and the new town of Cwmbran and is clearly the most favoured part of South Wales from the industrial point of view. It combines high diversity, low unemployment and a very high growth potential achieved with but little aid from government sources. The western division, although it has a fairly high growth potential, has more unemployment because of reorganisation in the steel and tinplate industries. To offset this it has a fairly high level of government activity and is, therefore, reasonably diverse except for Port Talbot.

The features of the mining valleys are the relatively undiverse industrial structures, the predominance of government initiative in

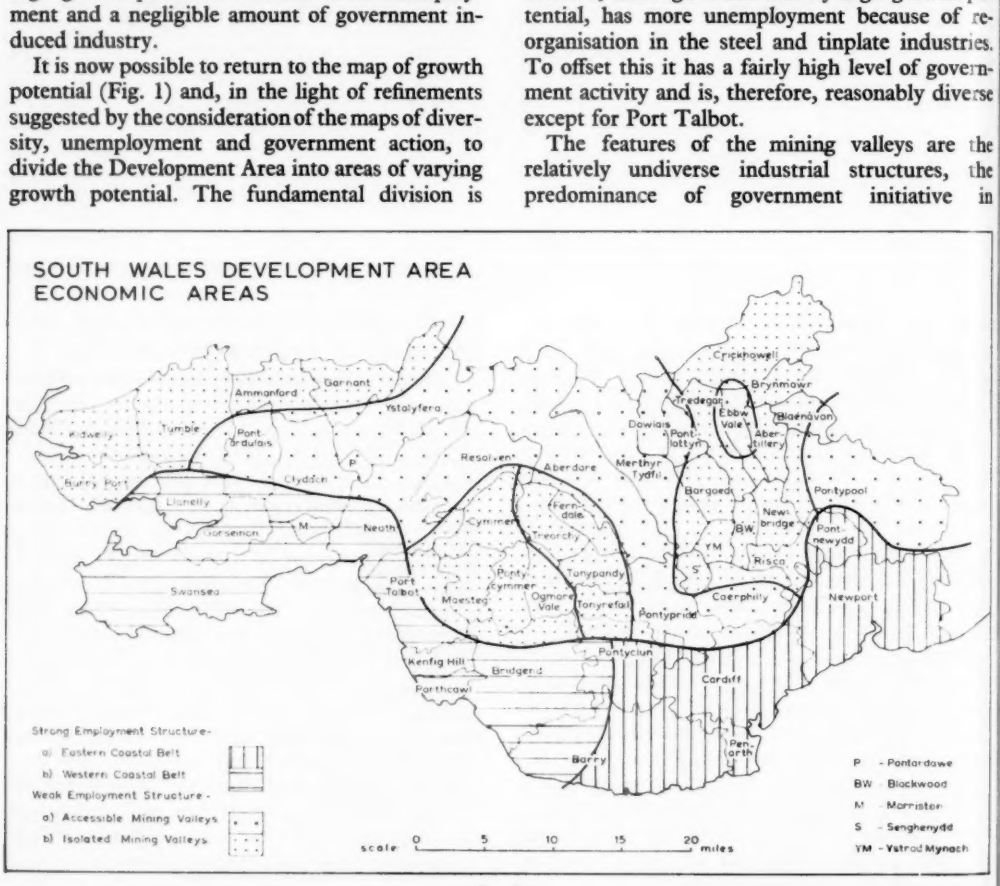


Fig. 5

manufacturing industry, and the low growth potential. These valleys, too, may be sub-divided into relatively more and relatively less favoured areas, the distinguishing factor being their geographical situation.

The relatively favoured valleys are the through valleys—the Swansea Valley, the Vale of Neath, the Taff and Cynon Valleys which form an arc from Swansea, through Aberdare and Merthyr to Cardiff, with an outlier around Pontypool. These valleys are easily accessible from the coastal fringe and also from the Heads of Valleys Road to the Midlands and from the routes to Mid-Wales.

The more remote valleys with poorer external communications are less favoured. They have very low potentialities for growth and, frequently, a highly undiverse economy mitigated only by a high level of government activity. Some of these areas do not have a high rate of unemployment, for instance the Ogmore and Garw Valleys; however, these are losing people by migration and there is daily travel to work southwards to Bridgend. Three of these less favoured areas may be identified. The Gwendraeth and Amman Valleys, areas of anthracite mining; the steam-coal area of Glamorgan, the Rhondda, Llynfi and Afan Valleys, with the Ogmore and Garw forming an even harder core to this relatively declining area; and the mining valleys of north-eastern Monmouthshire, the Rhymney, Sirhowy, Ebbw, Afan Lwyd and Clydach Valleys. Here is the real anomaly of the mining valleys, Ebbw Vale, which is an area of fairly high growth potential, low unemployment but an undiversified industrial structure. This results from one of the most anachronistic pieces of government intervention, the establishment of the steel works and strip mill before the war.

The division which this map (Fig. 5) shows differs from the standard industrial division in both extent and type. Whereas previous divisions were based on the location of industrial activity, the present one shows areas of potential economic growth and decline. It is therefore both dynamic and prescient. Such a differentiation, which has its physical expression in the landscape in such things as the proportion of new houses built by local authorities and by private individuals, is of great value for regional planning because it offers an explanation for the existence of the principle areas of economic and demographic change. In this, it affords a sounder basis for long-term regional planning than that which may be obtained from the purely statistical derivation of population and employment trends.

ACKNOWLEDGMENTS

This paper was prepared with the consent of the County Surveyor and Planning Officer to the Glamorgan County Council and is based on statistics held in his Department. We should stress, however, that none of the ideas or conclusions put forward in the paper is necessarily the expression of the opinions or policies of the Glamorgan County Council.

LOOKING AT science

FILMS ON CHEMISTRY

Between October 1959 and the end of May 1961, the British Association will have arranged seventeen Receptions for Science Teachers. These have been held with the generous co-operation of the following industrial organisations which have provided hospitality and projection facilities: British Oil & Cake Mills, Glasgow; I.C.I., Head Office; I.C.I., Billingham Division; I.C.I., Dyestuffs Division; Mullard's, Head Office; National Coal Board, Head Office; National Coal Board, Durham Division; National Coal Board, West Midlands Division; Shell International Petroleum Company, Head Office; Shell Mex & B.P., Head Office; Unilever, Head Office; Unilever, Merseyside.

Teachers have been invited to view a programme on recent films and to see some charts, filmstrips and other visual aids. The subjects dealt with have included biology, chemistry, general science, physics, and technical education. In two cases the general theme of science has been used to include teachers from a wide range of disciplines.

Below we give details of the chemistry films which have been shown at these receptions. These films have been selected as recent examples of the wide variety of material, either designed specifically for teaching or intended to give information to difference types of audience about the background, techniques, and problems of the chemical industry.

Whether the purpose of the film has been a teaching one, or has been concerned with some aspect of public relations, the films screened have been chosen as likely to interest teachers, either for curricular or extra-curricular use. They are not the only films likely to be suitable for such purposes, as indicated by the fact that the second edition of the Royal Institute of Chemistry's *An Index of Chemistry Films* (*see below*) gives details of more than 1200 films and 300 filmstrips, concerned with chemistry and the chemical industry.

To select appropriate material from such a large collection is a difficult job for the film information specialist, and a major task for the busy teacher. It is hoped, therefore, that this information will be of some help to those who wish to use films to present some aspect of chemistry, either to students for formal lessons, or to others who are active in Scientific Film Societies, Chemistry Societies and other extra-curricular activities.

AVIATION TURBINE FUELS

Sound colour 10 minutes Gt. Britain 1958

Produced by Shell International Petroleum, and available on free loan from Shell-Mex and B.P. Ltd., Shell-Mex House, Strand, London, W.C.2.

Kerosene, chosen for experiments with jet propulsion in 1941, is still the fuel used in gas turbine aero engines. Less volatile than gasolene it is slow to burn except when atomised, when it burns fiercely. This film includes a dramatic demonstration of these comparative properties and discusses such problems as icing and wax formation which beset the designer of engines for high altitude high speed aircraft.

Suitable for advanced students and science clubs.

THE BALANCE AND ITS USE

Sound colour 18 minutes Gt. Britain

Produced by I.C.I. Film Unit, and available on free loan from Imperial Chemical Industries Limited, Imperial Chemical House, Millbank, S.W.1.

After showing, briefly, some of the common everyday uses of weighing, the film contrasts these with the highly accurate techniques of the labora-

tory. It traces the development of the modern balance from the first crude Egyptian models and describes, in passing, the calibration of weights.

A short sequence illustrates the manufacture of a simple balance, stressing the precision of its assembly. Then follows the main section of the film—a detailed demonstration of the techniques for weighing a liquid and a powder on a typical schools balance.

The film ends by describing some of the more complex and unusual balances that industry uses.

Useful background information for G.C.E. students.

CRYSTALLIZATION

Sound colour 17 minutes Gt. Britain 1958

*Produced by I.C.I. Film Unit and available on free loan from Imperial Chemical Industries, Imperial Chemical House, Millbank, London, S.W.*1.

This film sets out to show how man can control the shape and size of crystals for manufacturing purposes. Cubic, dendritic and granular crystal shapes each have a special value and their manufacture is explained with the help of animation.

Sulphate of ammonia is used to illustrate the importance of crystal shape in the bulk handling of chemicals.

Suitable for O and A level, science clubs and scientific film societies.

THE DISSOCIATION OF NICKEL HYDROXIDE

Sound colour 23 minutes France

*Produced by L'Institut de Catalyse de Lyon, and available on hire from the French Institute, Queensberry Place, London, S.W.*7.

This film shows some of the research work of S. Teichner, R. Marcellini and P. Rue under the direction of M. Prettre, Professor of Industrial Chemistry. The rate of some reactions can depend on parameters which were not taken into account hitherto as, for instance, the geometric form of the pan containing the sample. Animated diagram, and time lapse photography supplement location shooting to show an experiment proving that the dissociation of nickel hydroxide does not proceed in the whole mass of the sample at once. The reaction depends not only on the properties of the solid but on certain experimental conditions.

A research record of possible value to A level students.

DISTILLATION

Sound colour 32 minutes Gt. Britain

*Produced by and available on free loan from Imperial Chemical Industries, Imperial Chemical House, London, S.W.*1.

The third film in the I.C.I. series designed to relate familiar laboratory experiments to industrial practice. Simple distillation, and fractional distillation are both dealt with with examples of laboratory experiments and large-scale industrial distillation.

Suitable for O and A level, science clubs, and scientific film societies.

FILTRATION

Sound colour 25 minutes Gt. Britain 1959

*Produced by I.C.I. Film Unit, and available on free loan from Imperial Chemical Industries Limited, Imperial Chemical House, Millbank, S.W.*1.

One of a series of films designed to show the relation between school laboratory techniques and the equivalent industrial process.

This film shows different methods of filtration by gravity, increased or reduced atmospheric pressure and centrifugal force.

Suitable for O and A level, science clubs, and scientific film societies.

AN INTRODUCTION TO ION EXCHANGE

Sound colour 27 minutes Gt. Britain 1960

*Produced for and available on free loan with field notes from the Permutit Company Limited, Permutit House, Gunnersbury Avenue, W.*4.

This film deals with the subject which ten years ago was the concern of only a small number of experts. It surveys the use of ion exchange in industry and research; examines the structure of ion exchange resins, and discusses the two most frequently used types—the strong acid cation exchanger and the strong base anion exchanger. Three typical laboratory experiments are shown—the separation, substitution and removal of ions, the last process being considered in greater detail to explain the basis of ion exchange technique.

Suitable for A level and perhaps for science societies.

OUTLINE OF DETERGENCY

Sound colour 15 minutes Gt. Britain 1960

Produced by Worldwide Pictures for Unilever Limited, and available on free loan from Unilever Film Library, Unilever House, Blackfriars, London, E.C.4.

Water alone is not very good at wetting things. This film demonstrates with live photography and animations how the detergent weakens the tension at the water surfaces; the basis construction of the detergent molecule, and the action of detergency as a cleansing agent.

Suitable for senior students in secondary modern schools, for O level students (of domestic science as well as chemistry) and for science clubs and scientific film societies.

PHARMACY FOR YOU—PART I

Sound black & white 20 minutes Gt. Britain 1959

Produced by Greenpark Productions Limited for Boots Pure Drug Co. Ltd., and available from Sound-Services Ltd., Wilton Crescent, Merton Park, London, S.W.19.

This film, sponsored by Boots Pure Drug Co. Ltd., describes the training and work of a pharmacist. Part I is intended as a general vocational guidance film to the profession and the second part discusses the career opportunities within the Boots organisation.

Useful career information for those about to leave school.

REFRIGERATION

Sound colour 31 minutes Gt. Britain 1960

Produced by and available on free loan from Imperial Chemical Industries, Imperial Chemical House, Millbank, London, S.W.1.

A popular presentation of the principles of the compression type of refrigerator. Applications shown range from the preservation of fish and frozen foods to the freezing of mercury to produce very accurate mouldings in industry.

Suitable for secondary modern and O level students, science clubs and scientific film societies.

RUSTODIAN

Sound colour 22 minutes Gt. Britain 1958

Produced by Verity Films for Associated Lead Manufacturers Ltd., and available from Associated Lead Manufacturers Ltd., Clements House, 14, Gresham Street, E.C.2.

An account of the wartime development of a calcium plumbate based paint exceptionally resistant to corrosion. The film provides examples of various tests to which the paint was exposed and discusses the origins of rust in a fractional discharge of electricity.

Suitable for secondary modern and O level students, science clubs, and scientific film societies. The advertising of a proprietary product may not be acceptable to many schools but there is a lot of useful information well expounded in this film.

SILICONES

Sound black & white 10 minutes Gt. Britain 1958

Produced by and available from Norman Macqueen, West Street, Bromley, Kent.

An account of the nature of silicones showing their varying properties ranging from hard brittle materials to jellies, greases and a putty-like substance. The industrial uses of silicones are discussed.

A useful background, suitable for O and A level students.

SMALL SCALE ORGANIC PREPARATIONS

Sound black & white 17 minutes Gt. Britain 1960

Produced by I.C.I. Film Unit, and available on free loan from Imperial Chemical Industries Limited, Imperial Chemical House, Millbank, S.W.1.

The preparation of ethyl bromide, and the conversion of nitrobenzene to aniline, and thence to acetanilide, are used to illustrate the major techniques used in small scale work in organic chemistry. Connections by both corks and ground glass joints are employed. The simple chemistry of the preparations is explained but the main emphasis is on the manipulative techniques involved in practical work on this scale.

Useful background information for G.C.E. students.

THE TECHNIQUES OF ORGANIC CHEMISTRY

Sound colour 11 minutes U.S.A. 1959

Produced by Young America Films Inc., and available on hire from Gateway Productions Ltd.

This is Part I of a series of films on laboratory techniques intended as a supplement to lectures and demonstrations. Part I deals with the assembly and use of laboratory equipment for distillation; the determination of a melting point; and the Rast determination of molecular weight.

The film is introduced by Professor Louis F. Fieser of Harvard University.

The other parts in the Series are as follows:

Part II (20 minutes)

Equipment. Solubility tests. Procedure for crystallisation. Clarification. Cholesterol from gall stones. Collection of a precipitate. Supersaturation.

Part III (12 minutes)

Extraction. Countercurrent distribution. Elution chromatography.

Part IV (19 minutes)

Martius Yellow. A synthetic sequence involving preparation from the yellow dye of six derived compounds.

A very useful teaching series of particular interest to A level students.

A VITAMIN EMERGES

Sound colour 15 minutes Gt. Britain 1957

Produced by Realist Film Unit and available free from Glaxo Laboratories, Greenford, Middlesex.

The story of thirty years of research culminating in the isolation of Vitamin B12. This shows the application of industrial research to the solution of a medical problem—in this case the cure of pernicious anaemia which is characterised by the abnormality of marrow cells. It includes examples of the use of chromotography including one of the earliest uses of partition chromotography.

Useful background information, suitable for A level students.

INDEX OF CHEMISTRY FILMS—2nd Edition

Royal Institute of Chemistry, 30, *Russell Square, London, W.C.*1. *Price 5s.*

The Royal Institute of Chemistry has published a second edition of its *Index of Chemistry Films*. This new edition contains up-to-date details of about 1,200 films and 300 filmstrips on chemistry and related topics, classified by subject. Details of the addresses of distributors of the films are printed together with an alphabetical index by film title.

This new edition contains details of about 400 more films than were listed in the first edition published in 1959, an indication of the volume of film production in this field.

A serious criticism of the first edition was the lack of information about dates of production, and this has been remedied in the new edition where such information is available. It is a pity, however, that the new edition has an identical cover to that of the first edition (with the exception of the substitution of 1961 for 1959 on the spine). It would have been easier for users had the new edition been more easily distinguishable; and possibly would more easily promote sales of the new catalogue.

This should prove an indispensable work of reference not only for those who use chemistry films for teaching, but for all who are concerned with the presentation of films on aspects of the work of the Chemical Industry. The catalogue may be ordered direct from the Royal Institute of Chemistry.

THE MAGNETIC FIELD OF THE GALAXY

By R. D. DAVIES *Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield*

The study of the magnetic field of the Milky Way, our own Galaxy, is scarcely more than ten years old. As in many branches of science, attention was drawn to this subject by an accidental discovery. In 1949 Hiltner working at the Yerkes and MacDonald Observatories in the United States, was investigating certain stars to see if the light emitted from them was polarised as predicted by a theory current at that time. Although he found evidence for this polarisation in this particular family of stars he also found that nearly all the distant stars showed polarisation and that the direction of polarisation in each case was nearly the same, being directed along the plane of the Milky Way. At the same time he noticed an important correlation, namely that all the stars which were polarised were reddened due to their passage through interstellar dust clouds. This correlation led him to suppose that the polarisation had nothing to do with the star itself but was imprinted on the starlight during its passage through the interstellar dust clouds. Such a polarisation effect can arise from reflection by elongated particles which have been lined up uniformly in an interstellar dust cloud. It is common experience that the light reflected from a mirror or roadway is polarised, that is the vibrations are more intense in one plane than any other; car drivers wear Polaroid glasses which accept only light vibrations in the vertical plane whereas they exclude the reflected vibrations from the road which are in the horizontal plane.

The starlight which passes through interstellar dust is reflected so that it is polarised parallel to the long axis of the particles. Accordingly the rest of the light which passes straight on to the observer is deficient in that polarisation and has therefore a net polarisation at right angles to the long axis of the dust particles. It is observed that the net polarisation is parallel to the plane of the Milky Way and so the particles are elongated perpendicular to this plane. The required elongation is only 1·5 to 1.

Our real interest in this subject is in the mechanism which lines up these minute grains about ten-millionths of a centimetre in diameter and keeps them lined up uniformly over distances of several thousand light years. The magnetic field of the Galaxy is commonly supposed to be responsible. The most promising theory suggests that the grains will be spinning with their long axes perpendicular to the magnetic field. This makes the galactic magnetic field lie in the plane of the Galaxy. This theory however is unable to give us any indication of the exact magnitude of the field except that it should lie in the range 10^{-5} to 10^{-6} oersted if the theory is to apply at all.

Another important aspect of these optical measurements is the light they throw on the orderliness and the alignment of the galactic magnetic field. Even though the light from different stars traverses different dust clouds on its passage to the Earth the polarisation angle observed is constant over large areas in the galactic plane. This indicates that the magnetic field is uniform in direction over these vast volumes of space and is not distorted, varying in direction from one cloud to the next. Also an examination of the pattern of the alignment of the polarisation around the galactic plane shows a significant feature. In directions at right angles to the galactic spiral structure in say the constellation of Perseus the alignment pattern is remarkably uniform indicating that we are looking at right angles to the magnetic field which produces the alignment. On the other hand when looking down the length of a spiral arm in the direction of the constellation of Cygnus the alignment is completely

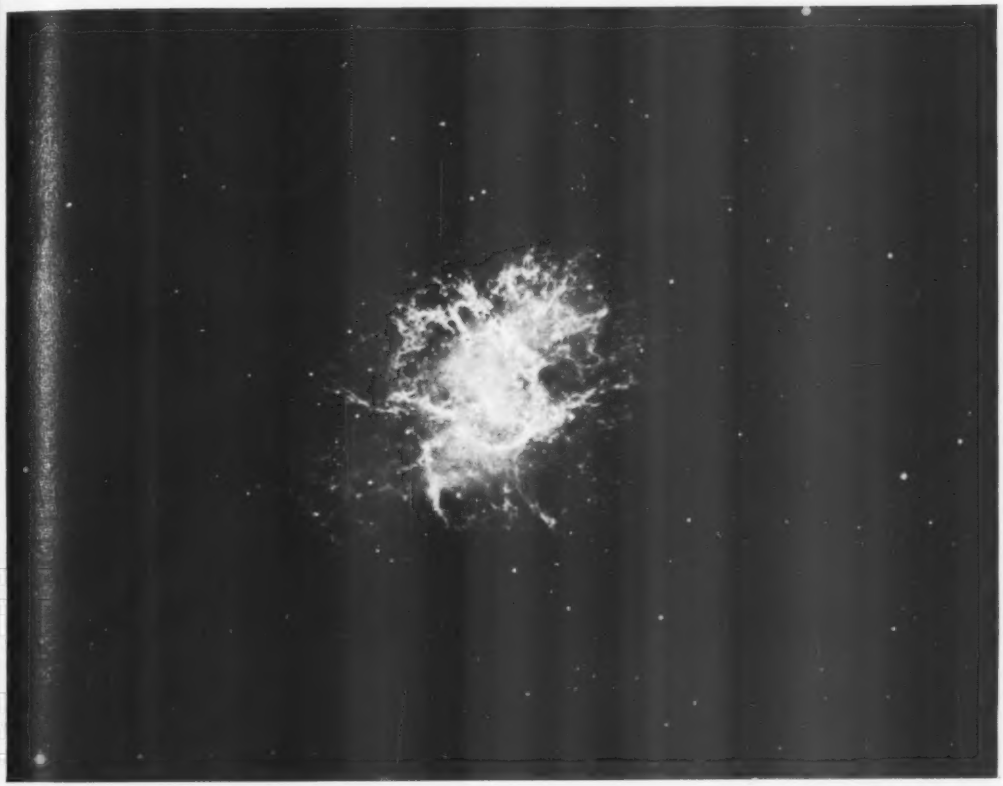


Fig. 1.—The Crab Nebula, which is the expanding remnant of the supernova of A.D. 1054. This, like a number of other supernova remnants is a radio source. Both its optical and radio emissions are polarised, indicating the presence of magnetic fields of about 10^{-3} oersted. (*By courtesy of the Mount Wilson and Palomar Observatories.*)

haphazard showing that here the line of sight is along the direction of the magnetic field. From these observations it is concluded that the galactic magnetic field is aligned along the spiral arms of the Galaxy so that the field lines run approximately along the arc of a circle at any point.

A general galactic magnetic field is invoked to explain a number of properties of cosmic rays. These high energy atoms of low atomic mass probably originate near the plane of the Galaxy in the supernova explosions. Because of their high energy they can only be held in the Galaxy by magnetic fields which pervade not only the regions near the plane but also the sphere which encloses the entire galactic system. In the presence of a magnetic field charged particles execute helical paths of large radius and for the Galaxy to hold a cosmic ray particle the radius of the orbit must be rather smaller than the size of the halo. In order that the orbit be less than this critical size the magnetic field must be greater than about 5×10^{-6} oersted in the halo.

Magnetic fields of this size are also required to make the distribution of the cosmic rays isotropic on the Earth. Since cosmic rays arrive in the vicinity of the Earth in equal intensities from all directions they must have been reflected, and maybe accelerated, by magnetic fields in the galactic halo.

In recent years radio astronomers have come to

realise the importance of magnetic fields in the production of radio waves in radio sources and in the radio Galaxy. The Crab nebula (Fig. 1) which is the remnant of an exploded star (supernova) is also an intense emitter of radio waves which are produced during the spiralling of high energy electrons around the strong magnetic fields inside the nebula. Such a process of radio and light emission is called synchrotron radiation and derives its name from the machine used in atomic and nuclear physics to produce high energy particles by forcing them to spiral around strong magnetic field lines. A distinguishing feature of this type of radiation is its polarisation both in the radio and optical domain; this polarisation has been measured by both methods in the Crab nebula and M87, the external galaxy with the jet observed in the Virgo Cluster.

The energy of the electrons required to give radio emission by the synchrotron mechanism is about 10^{11} electron volts (i.e. 10 times higher than is possible by man-made particle accelerators). Electrons of these energies probably arise from collisions of the galactic cosmic rays with the interstellar gas.

If we study the distribution of brightness about the radio sky we conclude that there are two distinct components. One is a flat distribution centred about the plane of the Milky Way and is called the disc component. The other is an almost spherical distribution which completely encompasses the disk and has a diameter of about 100,000 light years. It is not surprising that the latter distribution is similar to that of the magnetic field required to explain properties of cosmic rays for these same cosmic rays and magnetic fields are responsible for the radio emission from the halo of our Galaxy. A glance at a radio map of the Andromeda Nebula (Figs. 2, 3) shows how the halo and disc of our own Galaxy would appear if viewed from a distance.

An absolute value for the magnetic field in the galactic disc has been derived from the observed radio emission from the disc using various assumptions about the origin of the gyrating electrons. This estimate lies in the range $2-3\times10^{-5}$ oersted.

All the observations described above give only an indirect indication of the strength of the galactic magnetic field. An accurate measurement is now required to act as an anchor for theory. Such

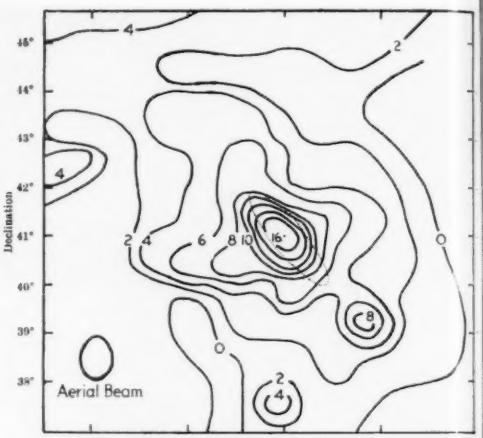


Fig. 2.—A map of the radio emission from the Andromeda Nebula at a frequency of 408 Mc/s. The outlines of the optical nebula (shown dotted) enclose the disc component. The halo component is roughly spherical and is much larger, having a diameter of about 6°. (*By courtesy of Dr. M. I. Large and the Editors of 'Nature'.*)

measurements have been attempted at Jodrell Bank during this Spring by Messrs. Slater, Shuter, Wild and myself.

Zeeman in 1896 discovered that light emitted from a gas in the presence of a magnetic field was polarised. Indeed when viewed along the lines of the magnetic field this light was split into two circularly polarised components in opposite senses which were displaced in frequency relative to one another. The amount of this displacement is proportional to the magnetic field in the line of sight and gives a technique for mapping magnetic fields. Such a technique has already been used in optical astronomy for mapping the magnetic field of the Sun. In that case fields of from 1 to 4000 oersted are detected compared with the Earth's magnetic field of half an oersted. In our experiment we were trying to measure fields of one gamma or less (1 gamma $=10^{-5}$ oersted).

The Zeeman experiment requires measurements on some spectral feature which is narrow in frequency. In the present case we chose the narrow features in the neutral hydrogen absorption spectra of the intense radio sources. This meant that the measured field referred to conditions inside the

dense neutral hydrogen clouds lying in front of these sources. The Cassiopeia-A source which is the brightest in the sky was the one most conveniently placed for this experiment because in this direction we look almost straight down the length of a spiral arm where the Zeeman effect is strongest. Measurements were also made on the sources Taurus-A and Sagittarius-A (see Fig. 4.)

We were unable to find any positive evidence for a magnetic field in these clouds. Any field if it existed at all was determined to be less than one gamma and possibly less than 0·5 gamma. Such a low limit to the galactic magnetic field comes as a surprise to some. Theories which require magnetic fields lying between 10^{-5} and 10^{-4} oersted will have to be reconsidered. These include certain

(*By courtesy of the Mount Wilson and Palomar Observatories*)

Fig. 3.—The Andromeda Nebula. The scale is 7.5 times larger than in Fig. 2.

theories about the lining-up process for the interstellar dust grains, theories of the generation of radio waves in the galactic disc and other theories relating to the formation of the spiral structure in the Galaxy.

Some interesting magnetometer results which partially corroborate the present observations have been obtained from the telemetered data from Pioneer V. Much of this telemetered information, incidentally, was being obtained by the 250 ft. radio telescope during the day-time while the 'Zeeman' group was operating the telescope during the night. The magnetometer on this 'deep space' probe was able to measure the field in interplanetary space when it moved away from the Earth's magnetic field. This interplanetary field showed a steady minimum value of about 2 gammas; from time to time it rose to about 5 gammas or more when it intercepted charged clouds shot out from the Sun. Several times the measured field fell to about one gamma. Another interesting result of these magnetometer measures is that the interplanetary field is perpendicular to the plane through the equator of the Sun. This means that if the field is interpreted as due to the Sun, then it cannot be that of a dipole centred on the Sun for it would require a permanent field of about 200 oersted on the surface of the Sun. No field of this magnitude is observed and it has been suggested that the interplanetary field may arise from an electrical ring current about 20 solar radii from the solar surface.

Whatever the origin of this interplanetary field may be, the measurements also give an upper limit to the galactic field in the solar neighbourhood (within a few light minutes of the Earth). The minimum field observed was one gamma and this must be taken as an upper limit to the galactic field. By comparison the Zeeman results obtained at Jodrell Bank refer to much larger samples of interstellar space. The clouds studied are each of the order of 30 light years in diameter and are distributed over a distance of 10,000 light years. It will be a valuable satellite experiment to try and detect magnetic fields much further from the Sun, say near the orbit of Mars or Jupiter.

A good knowledge of the magnitude and distribution of the magnetic field in the Galaxy is necessary for an understanding of one of the big problems in astronomy today. Why is the spiral

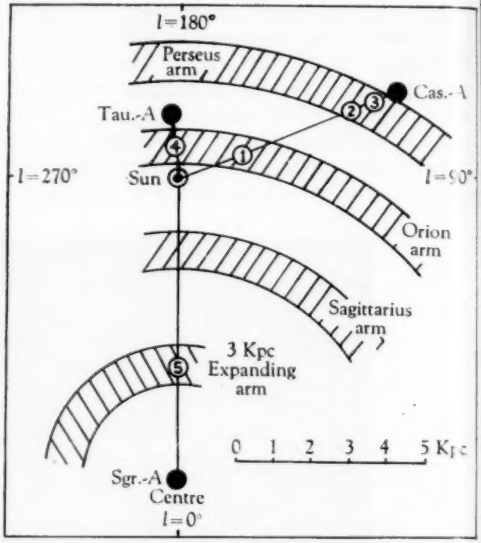


Fig. 4.—A schematic diagram showing the position in the Galaxy of the five neutral hydrogen clouds studied in the 'Zeeman' experiment. The clouds in the direction of Cassiopeia-A are most suitable for this experiment because the line of sight to them makes only a small angle with the magnetic fields lying along the spiral arms. (*By courtesy of the Editors of 'Nature'.*)

structure in galaxies so stable? Spiral galaxies constitute a substantial proportion of all the galaxies known. Since they presumably have ages of at least 5×10^9 years spiral structure must be very stable or else the spirals would have wound up (the rotation time for a galaxy is about 2×10^8 years) or dispersed due to the random motions of the clouds and stars of which they are composed. The constraining agent which is assumed to keep the spirals intact is commonly accepted to be the general magnetic field of the Galaxy.

Having set a provocative upper limit to the galactic magnetic field it is now extremely important to push the measurements using the Zeeman effect to a higher sensitivity. This involves incorporating new low noise radio astronomy receivers into the experiment. Although the techniques are demanding, the effort will be justified in order to elucidate the origin of radio waves in the Galaxy and to come to a better understanding of its spiral structure.

COMMUNICATING WITH CALIBAN*

By Prof. H. J. EYSENCK *Dept. of Psychology, University of London*

I. The Conditioned Reflex as a Means of Communication

Man has received three great blows to his self-satisfied view of himself as the centre of the Universe. First, Copernicus displaced the earth from the literal centre of all the suns, moons, planets and stars into the insignificant position of a small satellite of a medium-sized star on the outskirts of a relatively negligible galactic system. Next, Darwin showed that far from being unique, man was in fact first cousin to the ape. Third and last, Pavlov has succeeded in showing that much of the activity of *homo sapiens* can be accounted for in terms of simple associations of a purely fortuitous kind between stimuli impinging on man's sensory surfaces, and responses mediated by his skeletal, glandular and autonomic systems. In thus reducing man to the status of a machine, Pavlov was only one of a long line of predecessors going back to Descartes, Condillac, Condorcet, and many others, just as Copernicus and Darwin also had predecessors holding similar views. What Pavlov added was an experimental method which enabled his theories to be put to the test, to be investigated empirically and to be elaborated in the form of general scientific laws.

Like most great scientific theories, the notion of the conditioned reflex is deceptively simple and obvious; it will be remembered that George Bernard Shaw accused Pavlov of being a charlatan because every animal trainer is familiar with the elementary facts of conditioning. This, of course, is true in the same way that most people are familiar with the simple facts of gravitation, i.e. that if you drop a plate it falls to the ground and gets broken. This does not mean that Newton was a charlatan in elaborating the laws according to which gravitation works, and in applying them to phenomena not until then thought of in relation to gravitational forces, such as the precession of the equinoxes, or the phenomena of the tides. Pavlov not only discovered conditioning, but he laid bare the laws according to which it operates and showed how it could be applied in situations which had previously not been thought of in relation to conditioning.

His original experiments, of course, are familiar to most people. Take a hungry dog, put him in a soundproof room from which all disturbing stimuli, including the experimeter, are excluded. Stimuli are presented and reactions observed from outside the room, through devices such as a one-way screen, and the dog is prepared for the experiment by attaching a little glass funnel to his salivary glands so that the amount and rate of salivation can easily be led away by means of a rubber tube and used to make a record on a tracing device outside the room. The experimeter makes use of two kinds of stimuli. First there are blinking lights, ticking metronomes, buzzers, bells and so on, all of which are called neutral, or *conditioned stimuli* because they do not evoke the response in which the experimeter is interested, i.e. in this case salivation. Other stimuli, such as the presentation of meat powder, or some other food, are called *unconditioned stimuli* because they evoke directly the response in question. The conditioning experiment itself simply consists in pairing conditioned and unconditioned stimulus a number of times, i.e. ringing a bell and then immediately presenting the food to the animal; when this is done sufficiently frequently, it is found that the dog now salivates to

* Granada Lecture delivered in Guildhall on the evening of October 5, 1960.

the bell alone, even without the presentation of any food. In other words, the conditioned stimulus is not neutral any more but has acquired properties similar to those of the unconditioned stimulus, simply by virtue of having been paired with it a number of times.

Once acquired a conditioned stimulus is never forgotten, but remains until it is experimentally extinguished. This is done by repeatedly presenting the conditioned stimulus in isolation and without the unconditioned stimulus, i.e. by ringing the bell and not presenting any food; salivation gradually decreases and finally ceases. However, it is not a question of the animal 'forgetting', because if after a few days the conditioned stimulus is again presented, without the unconditioned stimulus, a strong reaction will be observed again which requires to be extinguished, and although extinction the second time proceeds more quickly, there is another recovery after a day or two, and another one after that so that extinction is not complete until after many periods of non-reinforcement.

This process of conditioning can be demonstrated as readily in human beings as in dogs. Fig. 2 illustrates the so-called eye-blink conditioning experiment in which the unconditioned stimulus is a puff of air, delivered direct to the cornea of the eye from a compressed-air container through a polythene tube which is inserted in a hole in the glass of a special set of spectacles, worn by the subject. The conditioned stimulus is a sound delivered over earphones, and the response is a blink of the eyelid which is registered through a change in the amount of light reflected on to a light-sensitive cell which can just be seen at the top of the spectacle frame; from this cell leads go to a high-speed recording device which gives a complete record of the movement of the eyelid.

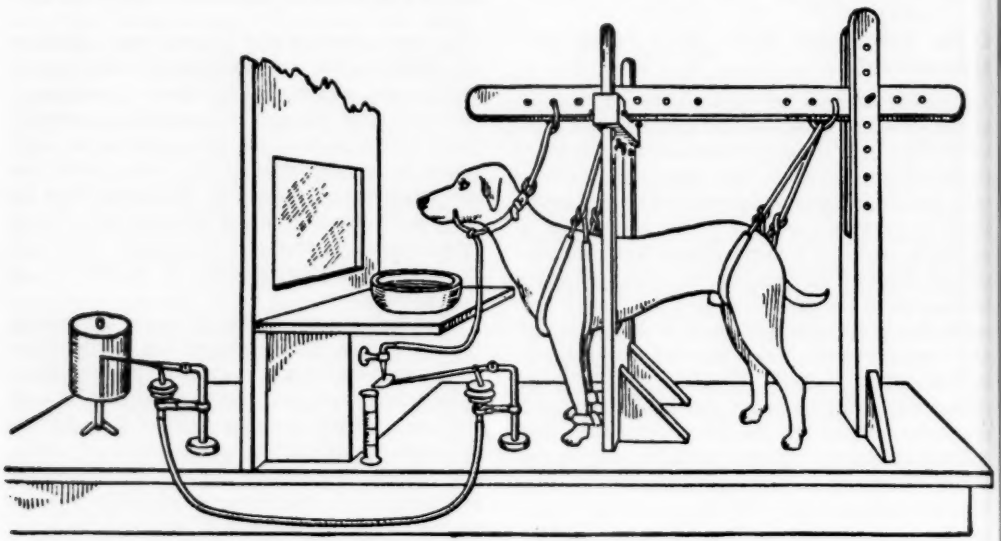


Fig.1—Diagram of Pavlovian conditioning experiment, with dog in stand and recording apparatus outside the room.

It is first established that the subject does not blink to the tone, but that he does blink to the puff; tone and puff are then paired a number of times, and after a while the subject is found to blink to the tone even without the puff. This blink is not by any means a voluntary defence reaction; it is quite easy to distinguish voluntary and conditioned responses on the basis of certain time characteristics which make malingering and faking impossible.

Fig. 2.—Human conditioning experiment, with subject separated from apparatus by curtain. The subject fixates red warning light, while tones (conditioned stimuli) are delivered over earphones and puffs of air (unconditioned stimuli) are delivered to the cornea of the eye through a polythene tube leading from the compressed-air container shown in the centre of the picture to a hole in the glass eye-piece in the spectacle frame worn by the subject. The apparatus shown on the right controls the timing of the stimuli.

Another method of conditioning human subjects is by means of the so-called *psychogalvanic response*. This consists of a rather curious drop in the resistance of the skin to the passage of an electric current; usually one electrode is fixed to the palm of the hand, the other to the back, and the resistance recorded on a special device. Any sudden shock or emotion lowers the resistance, probably because it leads to a slight and often almost imperceptible degree of sweating in the palm which facilitates the passage of the electric current. The puff of air to the eye is sufficient to produce such a slight shock which is followed by a lowering of resistance, and by pairing the tone with the puff of air, we can soon condition the psychogalvanic response to occur to the tone alone. Fig. 3 shows a portion of a record in which both eye-blink and P.G.R. have been recorded; the first response on the left is to tone and puff combined, with the P.G.R. deflection at the top of the page and the eye-blink at the bottom. Near the right-hand side of the figure we have a tone stimulus alone and it will be seen that it too is followed by both the P.G.R. and an eye-blink reaction. There are, of course, many other ways of studying the conditioning of human subjects in the laboratory, but these two have been used perhaps more frequently than any others.

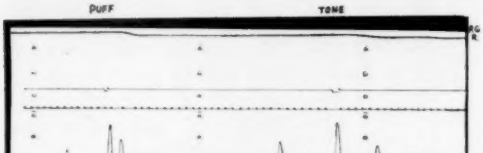


Fig. 3.—Typical record of conditioning experiment. The line at the top (marked PGR at the right) shows the variation in skin conductivity as a function of unconditioned (puff) and conditioned (tone) stimuli. The occurrence of these stimuli is indicated on the second line, while the third line gives the time base. The bottom line shows eye-blink responses.

In a sense, conditioning of the psychogalvanic response is more typical of conditioning experiments generally than is eye-blink conditioning. The reason for this is related to the existence of two relatively distinct types of nervous system which we all possess. On the one hand there is the *central nervous system* which mediates our perceptions—sound, sight, touch, pain and so forth, and which also transmits impulses from the brain to the muscles attached to the skeleton, thus enabling us to make so-called voluntary movements. In addition, however, we also have the so-called *autonomic nervous system* which is concerned with largely unconscious types of activity, such as heart beat, regulation of the size of the pupil, sweating, the number of red corpuscles in the blood, rate of breathing, and so forth. These reactions are involuntary, they continue during sleep, and many of them are closely related to what we would normally call the emotions, particularly those of fear and anger. If you try and recollect an occasion when you were very angry, or very much afraid, you will recall vividly some autonomic reactions, such as the rapid beating of the heart, or quick intake of breath, or possibly the cessation of digestion and the accompanying drying up of the saliva in the mouth. You are unlikely to have noticed the dilatation of the pupil, the increase in the number of red blood corpuscles, and the pouring of adrenaline into the blood stream. All of these are useful in preparing the organism for fight or flight; they are the invariable accompaniment of strong emotion, and in the opinion of many they do in fact constitute the physiological basis of the emotion that is felt. Now, while it is possible to condition motor movements which are under the direction of the central nervous system, it is usually much easier to condition autonomic reactions, and indeed, Pavlov's original experiments were nearly all done with the salivary reflex which is governed by the autonomic system. The distinction between the central and autonomic system is important in physiology; equally important from the point of view of human behaviour is the distinction between voluntary behaviour and emotional behaviour, as mediated by these two systems. It will be the burden of my talk that conditioning constitutes a method of communication, a way of communicating with the emotional, often unconscious side of human nature, which takes its place by the side of the more widely recognized systems of communication by means of language and appeals to consciousness. It will also be argued that conditioning as a system of communication has been very much neglected, and that it explains many features of human conduct which otherwise are quite inexplicable.

Let me start with a simple experiment to demonstrate that these two systems may often act not only independently, but antagonistically. Let us take an experimental subject, put him in a chair and attach the electrodes to his hands for measurement of the psychogalvanic response. Let us attach to his legs a device for administering electric shocks, and let us introduce an apparatus into the room which projects words on a screen in front of the subject. There are ten such words, and these are presented in random order and with many repetitions. Five of them, the 'shock' words are always followed by shock, while another five, the 'non-shock' words, are never followed by shock. Very soon the subject is conditioned to respond with a P.G.R. to the shock words, even when no further shocks are administered to any words, but not to respond to the non-shock words.

We now decrease the brightness with which the words are projected to such an extent that the subject cannot read them any longer, but has to guess; under these conditions we discover an interesting phenomena. When the subject is asked to read out the word that is projected on to the screen, he may read out (erroneously) a non-shock word when a shock word is in fact presented. However, the recording device shows that his

autonomic system has responded correctly by producing a psychogalvanic response, thus contradicting his conscious guess. Conversely, the subject may guess that the word is a shock one when in actual fact it is not; under those conditions again the P.G.R. may deviate from his conscious guess by not responding. This is an experiment in what is sometimes known as *subliminal perception*, a topic around which there has been a good deal of discussion, particularly in relation to its possible use in advertising. It is extremely unlikely that the phenomena could be used for advertising purposes, but the facts do indicate, as in the experiment just recounted, that the conscious and the autonomic systems may respond differently and even antagonistically, to one and the same stimulus, and that therefore communication may be rather more complex and difficult than one would at first have imagined.

II. The Neurotic Paradox

Let us now turn to one of the great paradoxes of human life, the so-called *neurotic paradox*. As we all know, the behaviour of neurotics contradicts some of our apparently most firmly founded generalisations. We believe by and large that human beings will act in conformity with some form of hedonism; in other words, they will do the things which give them pleasure and avoid the things which give them pain, taking these terms in their widest possible sense. Yet consider a few neurotics. Mrs. Smith is suffering from a *cat phobia*, i.e. a fear of cats. This is so strong and unreasoning that it makes her life a complete misery. She cannot go out into the street in case a cat might jump out at her; she cannot go into the garden in case she should meet a cat, she cannot leave her room for fear of felines. She is condemned to a life of complete misery, although rationally she is quite prepared to admit that her fear is unreasoning and purposeless, and that there is nothing fearsome about cats. Such phobias are legion, and may embrace every conceivable object or idea. Fear of open spaces, fear of closed spaces, fear of animals, fear of people, fear of moving, fear of not moving—there is a wide and variegated set of sonorous Greek and Latin terms to cover most of the well-known phobias. But in essence they are all alike in showing an unreasoning fear which is known to be unreasoning by the sufferer, but nevertheless cannot be brushed aside.

Or consider compulsions. Here is a neurotic who has to wash his hands every time he touches another person, or something that has been touched by another person. He soon spends his whole day washing his hands, completely unable to earn a living or live any kind of normal life. Consider the patient suffering from 'anxiety state', a person full of vague fears and anxieties which may have no specific reference at all. He may not even have the excuse of the phobic patient, to wit, a specific object of which he is afraid; he may be afraid of a wide variety of objects, or just be anxious and afraid in general without any specific cause. The number of people suffering from these disorders is legion, and it is widely agreed that many patients who ostensibly come for other reasons to the doctor's surgery are in fact suffering from some form or other of neurotic illness. For hundreds of years attempts have been made to cure them by communicating with their conscious mind, by reasoning with them, by pointing out the absurdity of their actions, or the unnecessary complications introduced into their lives. None of these attempts have had the slightest effect because the attempt at communication has been directed at the wrong system. Let us see what the picture looks like if we substitute the principle of conditioning and extinction for that of rational persuasion.

The first to have done so was J. B. Watson, an American psychologist who carried out this work around the time of the First World War. He and his colleagues determined to test the hypothesis that phobias and other neurotic symptoms were maladaptive conditioned emotional responses; that they could be produced in the laboratory; and that they could be cured by means of certain extinction procedures. Watson's account of his experiment with little Albert, an eleven-month-old boy, has become famous. Little Albert was very fond of white rats, rabbits and other furry animals, and used to play with them whenever he had an opportunity. Watson placed him in one corner of a large room and stood behind him with a metal bar and hammer. Whenever Albert reached for the white rat which was placed in front of him (the conditioned stimulus), Watson would bang the iron bar, thus making a loud noise which frightened the little boy and caused fear and the accompanying

autonomic reactions. This loud noise (the unconditioned stimulus), following immediately after the conditioned stimulus, very shortly produced the predicted result; little Albert became afraid of white rats, refused to play with them, cried when they were brought into the room and developed other phobic symptoms. These extended to rabbits and other furry animals, as one would have predicted on the basis of a well-known feature of all conditioning procedures entitled 'stimulus generalisation'. An animal or a person conditioned to a particular stimulus, say a metronome going at the rate of 60 strokes a minute, will also respond to a metronome going at 30 or 120 strokes per minute, although the reaction will be less strong the greater the difference is between the new rate and the rate at which the original conditioning took place.

How to cure little Albert, and other children in whom phobias were experimentally produced? Watson made use of a principle which has lately been called that of *reciprocal inhibition*. I have already mentioned the close relationship between the autonomic system and emotion; it should be realised that the autonomic system in turn is made up of two antagonistic systems, entitled the sympathetic and parasympathetic. The sympathetic plays a major part in those reactions of fight and flight I have described already; the parasympathetic tends to act in the opposite direction. Thus, stimulation of the sympathetic stops digestion, dilates the pupil, increases the rate of breathing and so forth; stimulation of the parasympathetic stimulates digestion, decreases the size of the pupil and slows down the rate of breathing. The sympathetic, in brief, prepares the body for emergency reactions, the parasympathetic keeps it vegetating peacefully. Now Watson argued that he had succeeded in establishing a sympathetic conditioned response (fear) to rats in little Albert; to get rid of this, he required to establish a parasympathetic conditioned response which would be stronger than the sympathetic one, and being antagonistic to it would cancel it out. As an unconditioned stimulus he used pieces of chocolate, and as the conditioned stimulus, the white rat. However, there was one obvious difficulty in this; the conditioned fear response was so strong that little Albert would not even look at the chocolate when in close proximity to the rat. Watson made use of another well-known psychological principle, namely that of *arousal gradients*.

In Fig. 4 let the ordinate represent the strength of fear arousal produced by a white rat, and let the

Fig. 4.—Diagrammatic reproduction of the fear arousal gradient, showing a decline in fear with an increase in distance away. The broken line indicates the lowering of the total fear response through reciprocal inhibition.

abscissa represent the rat at various distances from little Albert. It will be seen that the greatest fear is aroused when the rat is close by, and that the further away the rat is, the less is the fear aroused. If we can find a distance away from little Albert at which the fear aroused by the rat is just smaller than the positive emotions aroused by the piece of chocolate (A in the diagram), then little Albert will grasp and eat the chocolate, thus beginning a parasympathetic conditioning process to the rat. This will lower the general level of the curve to the position indicated by the broken line, so that next time the rat can be advanced from distance A to distance B without producing a degree of fear which would interfere with the establishment of the conditioned parasympathetic response. In this way the rat, starting out at the far end of the room, can be brought nearer and nearer to little Albert, until finally he is munching away happily with the rat right next to him. Once this is achieved the phobia is cured, never to return. This is an experimental demonstration of how Watson thought neurotic symptoms originated, and a demonstration of one method which would lead to their cure.

You may wonder whether the study of actual adult neuroses would bear out this way of looking at the neurotic paradox. Consider the 'Case of the Wallpaper Man'. This is a middle-aged man,

happily married, who complains that for many years he has been impotent with his wife although very much in love with her. It appears that his impotence disappears whenever they go on holiday together. I will spare you the details of the investigation, but what finally emerged was this. As a young man the patient had had an affair with a married woman (perhaps I should add here that the patient was French). One day the husband surprised his wife in the patient's arms and beat him within an inch of his life, thus producing strong pain and fear reactions. According to the principle of conditioning, these would be expected to become conditioned to whatever happened to attract the patient's attention at the time. As it so happens he was looking at the wallpaper, so that we have a conditioned fear response to the sight of the wallpaper; the patient, of course, was not conscious of this. As you may have guessed by now, the patient's bedroom had on the wall exactly the same wallpaper as the bedroom in which he had been beaten up, and the conditioned fear response, through a physiological mechanism which is well understood, interfered with his potency and made it impossible for him to make love to his wife in that room. This particular patient did not require extensive therapy by means of the principle of reciprocal inhibition; it merely required the services of the paper-hanger to make his symptoms disappear.

It is, of course, only rarely that the chain of events is so obvious, or the cure so simple. The 'Case of the Cat Woman' I mentioned before is probably a more representative one. Here, as with little Albert, it was necessary to devise some kind of gradient of diminishing fear responses so that calming, fear-reducing conditioning could take place. This was achieved by getting her used to thinking of cats, to playing with models of cats, looking at pictures of cats and so forth, until after a relatively short time, the phobia was overcome very much in the same way as little Albert's, with not a trace remaining. The main exponent of this method of therapy by means of reciprocal inhibition has been Professor J. Wolpe, who has actually treated large numbers of cases showing all the classical neurotic symptoms, as well as the simple phobias which I have singled out here for description as they provide the clearest examples. He has compared his success rate with that reported by psychoanalysts, as well as with the best available estimates of spontaneous remission in neurotic disorders, and has come to some interesting conclusions. He finds that the success rate of psychoanalytic treatment and orthodox psychotherapy is not noticeably different from that of spontaneous recovery, but that treatment by means of the principle of reciprocal inhibition is very significantly superior to both. In addition, reciprocal inhibition takes much less time than psychoanalysis, needing on the average between twenty and thirty sessions.

Let me turn to some other behavioural disorders which are difficult to understand in terms of our ordinary thought processes. Let me quote an advertisement which appeared in a booklet entitled *Ladies Directory* which appears to be a kind of Who's Who of London harlotry. It is inserted by a 'Miss Wyplash (Ex-Governess)' who labels herself a 'strict disciplinarian' and appends her telephone number. Now it does not require an expert in these matters to come to the conclusion that we have here a young lady who is prepared to arouse the sexual passions of her customers by beating them with rods and whips. To the ordinary man in the street such masochistic delights are quite unintelligible, his only acquaintance with such instruments of punishment being of a painful and undesirable type.

However, let us consider another experiment. The dog is in his stand, but this time, instead of using a bell or buzzer as the conditioned stimulus for salivation we use an electric shock. This produces an obvious conflict between the arousal of the sympathetic system produced by the shock, and the arousal of the parasympathetic system produced by the food. If the shock is not too strong, then the animal becomes conditioned to it, ceases to struggle in his harness or to react with a withdrawal of the shocked foot. He actively seems to welcome the shock and to regard it as a pleasant stimulus to which he promptly salivates. If the shock is too strong, of course, the parasympathetic reaction is not powerful enough to overcome the sympathetic reaction, and the dog will become ungovernable, fight against his harness, refuse to take food, forget previously learned habits, and become 'neurotic'. The experiment shows that an unpleasant stimulus, provided it is not too strong, can be made to acquire a positive tone by making it the conditioned stimulus to a pleasant and agreeable experience.

Now consider the case of a young boy who is being beaten by the Headmaster, and let us assume that the Headmaster administers a beating which is not too severe. Quite frequently because of the position assumed, tight trousers and other obvious reasons the boy's sexual reflexes will be aroused at the same time, and as with the dog, the beating becomes the conditioned stimulus for these pleasant reactions. From then on the boy may seek actively the conditioned stimulus (the rod) as well as the unconditioned stimulus, just as the dog seems to welcome the electric shock. As you can see Miss Wyplash has much to be grateful for to Professor Pavlov. On another page of this invaluable book we find a 'Miss Fetishe', who apparently has 'theatrical wardrobe available—shoes—rubber hose, etc.' The explanation of fetishism in terms of conditioning will not present any great difficulties to the student of Pavlov. Thus an interesting case was reported recently in the *British Medical Journal* of a man who had a pram and handbag fetishism, due to two events in his youth involving, one a pram, the other a handbag. Psychoanalytic treatment established these facts, and led him to understand that these objects were for him 'symbolic sexual containers', but no cure ensued. A deconditioning process was commenced, in which 'a collection of handbags, permabulators and coloured illustrations was obtained and these were shown to the patient after he had received an injection of apomorphine and just before nausea was produced. The treatment was given two-hourly, day and night, no food was allowed, and at night amphetamine was used to keep him awake.' This aversive conditioning attempts to link the conditioned stimulus, in this case the prams and the handbags, with the unpleasant feelings aroused by the nausea consequent upon the injection. Apparently the treatment worked. 'After 5 days he said that the mere sight of the objects made him sick. He was now confined to bed and the prams and handbags were continually with him, the treatment being given at irregular intervals. On the evening of the ninth day he rang his bell and was found to be sobbing uncontrollably. He kept repeating, "Take them away".' The cure was quick, complete, and permanent. You may note certain interesting similarities in it to the process of 'brain-washing'; the main difference of course lies in the fact that the patient undergoes the treatment voluntarily.

Much the same argument may be applied to homosexuality, where the conditioned stimulus for sexual gratification may easily take the form of other members of the same sex when ordinary and biologically adequate stimuli are not present. It is curious that Society so much condemns homosexual practices whilst condoning the segregation of large members of adolescent and adult males without benefit of feminine company in such institutions as public schools, the armed forces, prisons and so forth. If it is true that he who wills the end must will the means, then it could be argued that if we wish to abolish homosexuality or at least largely reduce its impact, then we should take steps to avoid the conditions which lead to its growth, rather than punish the poor victim of a conditioning process over which he has no control.

If these theories about the growth of masochism, homosexuality and similar disorders are correct in their main outlines, then we should be able to extinguish the undesired responses along classical Pavlovian lines. In the dog which has become conditioned to respond with salivation to an electric shock, it is possible to extinguish the response by very much increasing the strength of the shock. Similarly, if we gave Miss Wyplash some training in really applying the whip properly we might have no more trouble with her clients. In regard to homosexuality the only one to have carried out experiments along these lines has been a Czech psychiatrist who gave homosexual patients a drug which produced vomiting at the same time as they were shown pictures of nude males. This is a rather rudimentary technique which could be very much improved, but even as it stands his report suggests that the results are in no way inferior to the effects of psychoanalystic treatment for similar cases.

Many people may be inclined to doubt the truth of this hypothesis because to them the strength of the masochistic and homosexual tendencies, and their apparent 'naturalness' makes them appear inborn characteristics, rather than acquired ones. The truth appears to be however, that, conversely, many of the sexual practices we regard as natural and inevitable are rather the result of a process of conditioning. We regard it as natural that sexual passion should be expressed through kisses and caresses; as another advertiser in the *Ladies Direc-*

tory ('voluptuous red head model Karan, 42-24-36') puts it:

'The girl you can trust
Is the one with the bust.'

Yet there exist many communities which are ignorant of the practice of kissing, and regard it as disgusting, and to whom the female bosom has a purely utilitarian function. This suggests very strongly that these other sex customs are acquired through a process of conditioning, although to us they may seem 'natural' and innate.

III. Conscience as a Conditioned Reflex

So far I have been talking about conditioned responses which are maladapted and which we may wish to get rid of—phobic reponses, homosexual ones, unreasoning anxieties and fears, compulsive and obsessional habits and so forth. There is, however, another side to this process of conditioning. While sometimes conditioned responses are maladaptive, often they are not, and in many cases we have to deal with people who have not acquired conditioned responses which Society regards as essential, or at least desirable. One simple example is *enuresis nocturna*, or the practice of wetting one's bed during the night. A very large number of children who go to Child Guidance Clinics suffer from this distressing trouble which is very reluctant to yield to psychotherapeutic procedures. Where the normal child has established the conditioned response of waking up to the increased pressure on the bladder which precedes urination, the bed-wetter apparently has failed to do so. How can we help him? The answer appears to be along the following lines. We make the child sleep on a blanket which has embedded in it two electrodes close to each other. These are connected to a battery and an alarm clock, and when the child urinates the circuit is closed and the alarm bell rings. The conditioned stimulus (pressure on the bladder) just precedes the unconditioned stimulus for waking up (the alarm bell) and after a number of repetitions conditioning takes place and the child wakes up to the pressure of the bladder, goes to the toilet and ceases to be an item in the statistics relating to *enuresis nocturna*. This method has been shown many times to work extremely well and to cure rapidly even quite serious cases. It use has not led, as many psychiatrists believed at one time, to increases in anxiety or other symptom substitutions. Quite the contrary appears to be the case. Bed-wetting causes a lot of tension in the family which leads to anxiety on the part of the child; cure the bed-wetting and the anxiety also will usually disappear. (Much the same can be said, incidentally, of the other types of treatment I have mentioned earlier on. There has been no symptom substitution, as might have been expected on psychoanalytic theories, but the clearing up of the main symptom has led to an improvement all round. Nor has there been any resuscitation or recrudescence of the symptoms.)

Psychiatrists sometimes say: 'Ah, yes; I have tried this method but it didn't work too well.' Such a statement leaves out of account the fact that conditioning methods require precision and experience which are not usually found among non-psychologists. Thus for instance eye-blink conditioning proceeds best when the interval between the tone and the puff is 450 milliseconds; there is no conditioning at all when the interval is 2 seconds or more. Reports of failure are only meaningful when the experiment is properly carried out by a fully qualified psychologist; in anybody else's hands failure to duplicate well-established findings throws doubt on the competence of the practitioner, rather than on the correctness of the theory.

Enuresis is one example of a missing conditioned response which requires to be reinstated. A much more important disorder exemplifying the same principle is that expressing itself in the so-called psychopathic states. Psychopaths as defined by the Royal Medico-Psychological Association are persons whose 'daily behaviour shows a want of social responsibility and of consideration for others, of prudence and foresight and of ability to act in their best interests. Their persistent anti-social mode of conduct may include inefficiency, and lack of interest in any form of occupation; pathological lying, swindling and slandering; alcoholism and drug addiction; sexual offences, and violent actions with little motivation and an entire absence of selfrestraint, which may go as far as homicide. Punishment or the threat of punishment influences their behaviour only momentarily and the more lasting effect is to intensify their vindictiveness and antisocial attitude.' Caliban may be said to be the prototype of the psychopath, 'a devil, a born devil, on whose nature nurture can never stick'; a being 'which any print of goodness wilt not take, being capable of all ill!'; one 'whom stripes may move,

not kindness'. Prospero succeeded in teaching him intellectual things, 'took pains to make thee speak, taught thee each hour one thing or other'; but in the end 'thy vile race, though thou didst learn, had that in't which good natures could not abide to be with'.

Extreme psychopaths are probably relatively rare, although they do present a very difficult problem to society. Milder forms are much more frequent, and there can be few people who have not been in contact with and suffered from the actions of such people. They have sometimes been called 'moral imbeciles', an appellation which well characterises their lack of social sense in spite of their possession of adequate or even superior intellectual powers. What has gone wrong? Some answers are given in terms which tend to beg the question. It is perfectly true but not very useful to say that these people behave as they do because they have no 'conscience', no 'inner guiding light', or no adequate 'super-ego'. The real problem that concerns us is to establish why these people have no conscience or whatever you may like to call this 'still inner voice'. Actually the problem is perhaps wrongly put. The psychopath behaves, as do most animals and most children, particularly very young ones; he seeks with all his powers the immediate satisfaction of every desire and whim without regard for long-term consequences. The real problem that arises is: why don't we all behave in this fashion?

I can only indicate what I believe to be the true answer very briefly and schematically. Essentially I would maintain that conscience is a conditioned response. We do not behave in socially accepted ways because we fear ultimate punishment; this is a widely held view which has very little to commend it. Countless experiments have shown that rewards and punishments which are long delayed do not affect conduct to any considerable extent, particularly when their occurrence is capricious and not very certain. The probability of being punished for a rape, say, is so small as to be very little deterrent. Why then is the number of rapes relatively small? The answer is that there has been provided through the process of socialisation an immediate punishment for anti-social acts which cannot be avoided, except by desisting from carrying out the act. This immediate punishment is a conditioned fear for which the appropriate conditioned stimulus is any overtly aggressive or sexual act which contravenes the rules of Society. The conditioning which establishes this anxiety and fear response has taken place many years before, when the child's parents, teachers and supervisors punished him every time that he indulged in activities of this type. This immediate punishment produces pain and fear reactions which condition to the particular act which precedes them and generalises to other similar reactions. Let me give you an experimental example from animal work to exemplify the kind of thing I have in mind. Take a large tank filled with water and place in it a pike and some minnows. The pike will race towards the minnows and eat them. Now put a sheet of glass into the water, dividing the tank in two and put some minnows into the part of the tank opposite the pike. The pike will again attack the minnows, but bump his nose very painfully against the glass partition. The pike does not learn easily, but after a few thousand repetitions he will cease to swim towards the minnows, and when the glass sheet has been removed he will not attack them, but will mingle freely with them. What has happened is simply that a conditioned pain response has become established to the series of perceptual and muscular events leading from the sight of the minnows to the attack upon them, so that the only possible way for the pike to avoid the painful conditioned response is to desist from making the attack. In other words, the pike has acquired a conscience!

I am not suggesting that the whole process is not very much more complex in human beings, particularly as language comes in to help in the generalisation of the conditioning process, identifying all forbidden things as 'bad'. Nevertheless, in principle the theory is not unreasonable, and in practice it has received much experimental support. Whether it will retain such support no-one can predict of course, but it does at least explain many phenomena which on any other theory are given up as inexplicable. It also explains why the 'conscience' of one tribe or nation may be so curiously different from that of another, a fact which would be difficult to explain in religious terms.

We now seem to have two great groups of people who are set apart in some measure from their fellow citizens. On the one hand we have our anxiety neurotics, phobics and compulsive-obsessional patients who have formed maladaptive conditioned

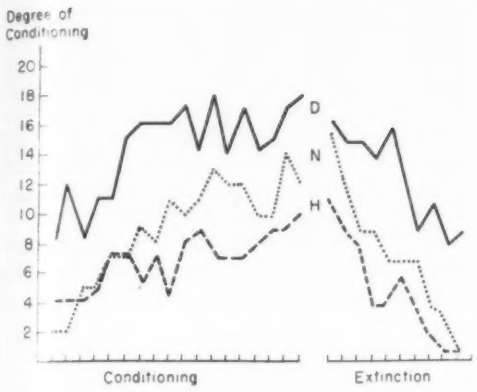


Fig. 5.—The growth of conditioning, and subsequent extinction of conditioned responses, during an experimental session of eye-blink conditioning. Three groups of subjects involved are: (1) Dysthymics (D), i.e. neurotics suffering from anxieties, phobias, depressive and obsessional symptoms; (2) a normal group (N); and (3) a group of hysterics and psychopaths (H). (*From H. J. Eysenck, 'Dynamics of Anxiety and Hysteria'. London: Routledge & Kegan Paul*, 1957.)

responses; on the other hand we have our psychopaths and hysterics who have failed to form the conditioned responses required by Society. Is it entirely due to the vicissitudes of environmental influences that a person falls into one of these groups, or is there possibly a constitutional predisposition which determines what he will become? Pavlov noted very early that dogs showed great individual differences in their response to the conditioning situation; some conditioned very quickly and strongly, others slowly and weakly, with the remainder intermediate between these two extremes. The same is true of human beings, and it is tempting to argue that perhaps the anxiety state or the phobic patient is what he is because of the constitutional tendency to form conditioned responses too quickly and too strongly, while the psychopath behaves as he does because he is constitutionally incapable of forming the strong conditioned responses required by Society sufficiently quickly. Such a hypothesis is capable of experimental investigation and Fig. 5 shows the rate of acquisition and the rate of extinction of the conditioned eye-blink response in groups of anxiety states, normal people, and hysterics and psychopaths. It will be seen that, as expected, the anxiety states (marked D in the diagram to denote a general *dysthymic* disorder) condition best, the hysterics and the psychopaths (marked H in the diagram) least well, with the normals (N) in between. Constitutional personality differences, therefore, appear to be strongly related to the person's behaviour pattern.

This theory can be taken a little further still. It was suggested by Jung, and has been verified since, that people who develop dysthymic disorders, i.e. the anxious, phobic, obsessional reactions, tend to be of the *introverted* personality type, while those who develop hysterical and psychopathic reactions tend to be of an *extraverted* personality type. These terms are probably too well known to require much explanation. The extravert is a sociable, happy-go-lucky, impulsive type of individual who likes activity rather than thought, and who is mainly interested in the outer world rather than his own mental processes, while the introvert is socially withdrawn, introspective, averse to taking risks, thoughtful and more interested in his inner life than in the outer world. In terms of this theory we would expect quite normal introverts to be more easily conditionable than normal extraverts and indeed, as Fig. 6 shows, this appears to be the case.

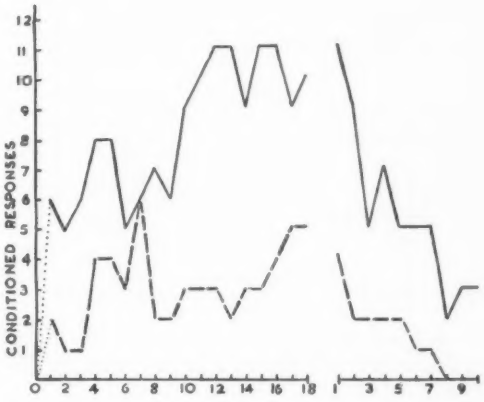
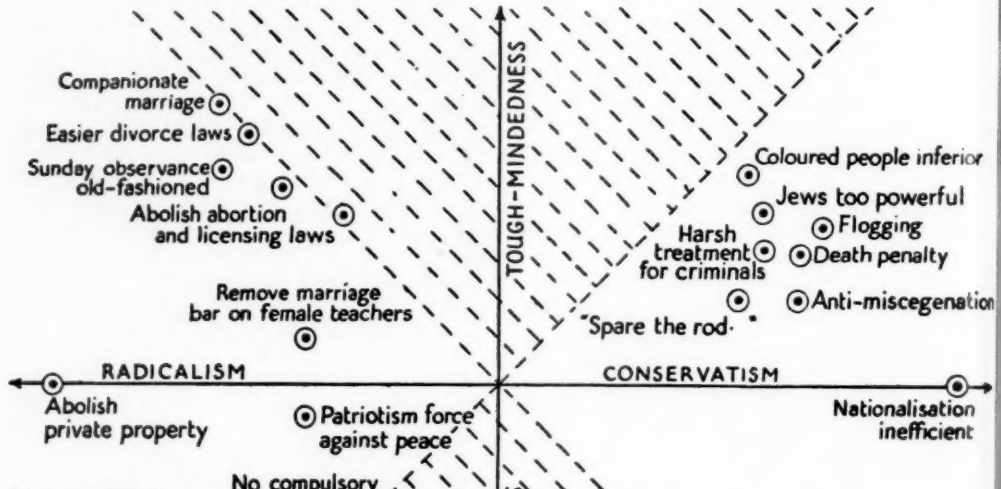


Fig. 6.—Growth and extinction of eye-blink conditioning in a group of introverted subjects (unbroken line) and extraverted subjects (broken line). Introverts are consistently superior to extraverts in degree of conditioning. (*From H. J. Eysenck, 'Dynamics of Anxiety and Hysteria'. London: Routledge & Kegan Paul*, 1957.)

IV. Conditioning and Social Attitudes

Introverts and extraverts differ in their general pattern of behaviour; it may be assumed that they will also differ with respect to their social attitudes. The introvert, being readily conditionable, would be expected to be more highly socialised, and to place particular value in his attitudes on religious and ethical barriers to the easy satisfaction of aggressive and sexual impulses. The extravert, on the other hand, due to his defective conditioning equipment, would be expected to favour the direct expression of aggressive and sexual impulses. In several large-scale studies the attitudes of large groups of English, French, German, Swedish and American subjects to a variety of social issues have been investigated. The resulting picture is surprisingly uniform and is as shown in Fig. 7.

This figure describes the results of a statistical analysis of the inter-relations between attitudes. When two attitudes are shown close together in the diagram that means that a person having one attitude is highly likely to have the other as well. When two attitudes are very far apart on the diagram, then the probability is that the person



Distribution of Attitudes with Respect to Tough-Mindedness and Radicalism

Fig. 7.—Distribution of attitudes with respect to tough-mindedness and radicalism. *(From H. J. Eysenck, 'The Psychology of Politics'. London: Routledge & Kegan Paul, 1954.)*

having the one, will not have the other. It will be seen that the clustering of attitudes is around two major poles or dimensions. One of these is the usual Conservative/Radical dimension which everyone is familiar with. It is the second dimension, however, which has been called tough-mindedness as opposed to tender-mindedness, which is of interest here. The tough-minded person favours flogging, companionate marriage, the colour bar, easy divorce laws, harsh treatment of criminals, the abolition of abortion laws and the keeping down of coloured

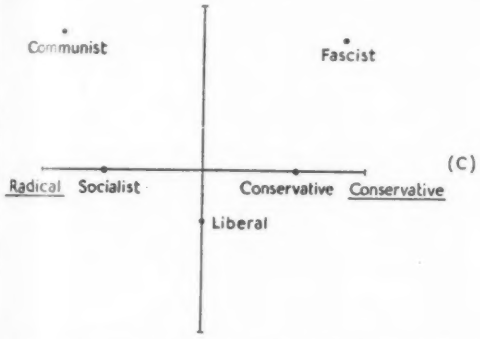


Fig. 8.—Diagram showing theoretical positions of five political parties with respect to Radical/Conservative axis with respect to tough-mindedness (top) and tender-mindedness (bottom). Actual experimental results with various groups are in good agreement with theory. (*From H. J. Eysenck, 'The Psychology of Politics'. London: Routledge & Kegan Paul*, 1954.)

people and Jews. The tender-minded person believes in going back to religion, favours pacificism and the giving up of national sovereignty and generally opposes the views of the tough-minded. These clusterings of views are in good agreement with the hypothesis, and it has indeed been found that, as predicted, the tough-minded people tend to be extraverted, tender-minded people introverted. When it comes to the position of members of political parties on this diagram, we find, as might have been expected, that both Communists and Fascists tend to be particularly tough-minded, whereas the Liberals are the most tender-minded group of all (Fig. 8). It is perhaps interesting to note that in this country differences between parties are mostly along the Radicalism/Conservatism axis; in France it has been found that the tough-minded/tender-minded axis was if anything more important. This may explain the difficulties English people often have in trying to understand French politics. In pre-war Germany, before Hitler came to power, the importance of the tough-minded versus tender-minded dichotomy was very much greater than that of the Conservative-Radical one. This suggests the possibility that the relative importance of these two sets of issues may be used as an index of democracy as opposed to totalitarianism in the comparison of one country with another, or perhaps even of one country at one time with the same country at another; modern Germany does not seem to resemble pre-Hitler Germany as much as it does England in this respect.

Another interesting fact which emerges is that middle-class groups tend to be more tender-minded than working-class groups, regardless of political affiliation; this is shown in Fig. 9, for Conservative, Socialist, Liberal and Communist groups of respectively middle-class and working-class origin.

It may be surprising to many people to find that I have here dealt with attitudes as if they were conditioned responses rather than rationally derived beliefs. Unfortunately, the evidence is fairly strong that social attitudes have little to do with reasoning,

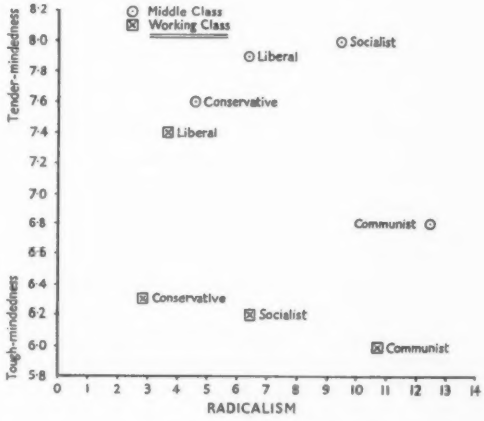


Fig. 9.—Degree of radicalism and tough-mindedness of middle-class as opposed to working-class groups voting for Conservative, Liberal, Socialist, or Communist candidates. (*From H. J. Eysenck, 'The Psychology of Politics'. London: Routledge & Kegan Paul*, 1954.)

but much with some form of conditioning. Consider Fig. 10 which shows the distribution of over 22,000 votes on an attitude scale ranging from very definite agreement through lesser degrees of conviction to very definite disagreement with various propositions, which were similar to those given in Fig. 7. Now most people would agree that the problems studied there—criminal punishment, divorce laws, nationalisation, religious education, conscientious objection, pacificism,—are highly complex and extremely difficult to answer yes or no to, even when all the facts about them are known. Indeed in the great majority of cases the only appropriate response would be 'don't know', or at best a very mild feeling that one or the other direction was the better of the two choices. Yet, as Fig. 10 indicates, about two-thirds of all votes were cast in the most extreme manner either pro or con, indicating that respondents were very certain that their views were correct.

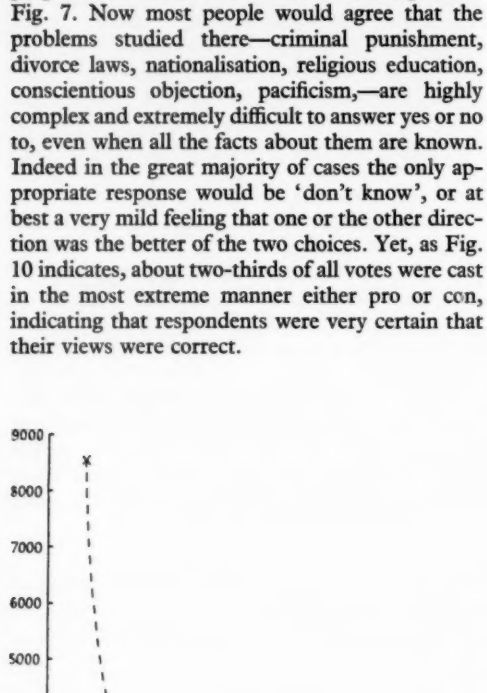


Fig. 10.—Distribution of 22,208 votes on a seven-point attitude scale. + 3 denotes very strong agreement with the statements presented; − 3 denotes very strong disagreement. Other numbers indicate lesser degrees of certainty. (*From H. J. Eysenck, 'The Psychology of Politics'. London: Routledge & Kegan Paul*, 1954.)

This is a general tendency which has been formulated as a general law, to wit, the so-called 'principle of certainty'. As given by the British psychologist Thouless, it reads as follows: 'When, in a group of persons, there are influences acting both in the direction of acceptance and of rejection of a belief, the result is not to make the majority adopt a lower degree of conviction, but to make some hold the belief with a high degree of conviction while others reject it also with a high degree of conviction.' This law accurately represents the facts, but it cannot easily be reconciled with the notion that social attitudes are formed in a rational manner. It is much more in agreement with the notion that attitudes express the end results of a long and complex process of conditioning. I suggest that the facts expressed in the 'principle of certainty' and in Fig. 10 are well worth pondering; they may contain the explanation for much of the industrial, political and international unrest and fighting that has bedevilled the history of mankind.

The evidence contained in Fig. 10 is of course indirect, but more direct evidence on ways in which attitudes can be conditioned comes from the work of the American psychologist Razran, who was once a student of Pavlov's. He ascertained the opinions of students on a variety of social issues, as well as on preferences for pictures, pieces of music and so forth. He then on a later occasion kept the students engaged on some experimental work until well after their lunch hour, and when they were really hungry he took them into a specially prepared room and gave them a particularly nice luncheon. This meal constituted the unconditioned stimulus; the conditioned stimulus was provided by pictures on the wall, pieces of music playing on the gramophone, pictures of political personalities representative of certain social attitudes, and other similar stimuli. Razran found, as had been predicted, that when the students were re-tested some time after the meal, the conditioned stimuli had increased in preference value due to the association with the pleasant meal. This principle, of course, is not unknown in the business world where a pleasant meal is often made the basis of business negotiations. I gather from newspaper reports that some American business concerns have extended this method a little by filing tax remission claims not only for the cost of meals, theatre tickets and so on to entertain business contacts, but also for the

salaries of a group of call girls. This may be a logical extension of Razran's work, but I am sure the University would frown upon actual experimentation to test its validity.

V. Conclusions

I must try now to pull together the main points I have attempted to make in this lecture. I have argued that the notion of rational man, acting in conformity with reason and knowledge and guided entirely by his brain, is erroneous, although it is still widespread and still governs many of our educational and social policies. Instead, I have suggested that much of human conduct is governed by the heart rather than the head; by emotion, rather than by reason. In much of what he does, man is Caliban rather than *homo sapiens*, and the language used to communicate with *homo sapiens* is not suited to communicating with Caliban. Emotions are not modified by argument; they are not acquired nor can they be extinguished by appeals to reason or other similar modes of communication. Emotional reactions can be conditioned, and they can be extinguished; we have available a considerable amount of experimental knowledge about these matters of communicating with emotional man. This knowledge suggests that many current methods used by Society to deal with its problems are useless or worse; it also suggests better methods which ought to be tried out to see whether in fact they fulfil their promise. I have concentrated on the problem of neurosis and its cure because my own work has largely been connected with these topics; I have no doubt, however, that similar applications of the principles of conditioning could be found in education, in criminology and many other fields. Even in the realm of advertising and market research it might not be surprising to discover that the use of Pavlovian findings might be more advantageous than reliance on the oddities of 'motivational research'.

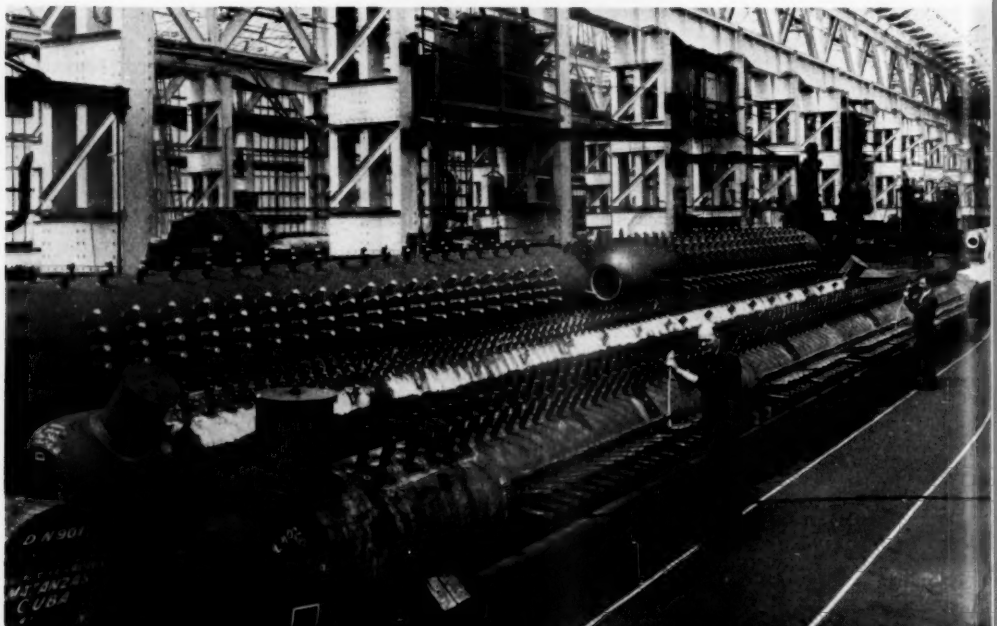
One other general conclusion emerges which I should like to stress particularly. You may find many psychologists, psychiatrists, psychoanalysts, sociologists, penologists and other experts writing books and giving evidence to Royal Commissions on the various social problems I have mentioned, from rearing children to dealing with criminals. Two things characterise most of these contributions. In the first place they are seldom based on solid research and laboratory investigations, but merely represent the personal opinions of the people concerned. In the second place, the opinions expressed usually contradict each other; indeed, experts have sometimes been defined as people who hold vehemently antagonistic views with great tenacity. Thus, to take but one example, you have the 'spare the rod and spoil the child' school opposed to the 'let the little darlings do as they like' school, with the pendulum slowly swinging from one to the other. We may perhaps regard these writings and beliefs as the last survivors of that 'ordeal by quackery' through which, according to a modern historian of science, every science has to pass before establishing itself firmly on an experimental, empirical level; psychology as a whole should not be judged by them.

Now if there is any truth in what I have said and if individuals do indeed differ in the speed with which they form conditioned responses, then it must follow that all the experts are likely to be partly right and partly wrong. It follows that one and the same way of treating children, or criminals, or any other group of people will have quite different results, according to the degree of conditionability of each of the people concerned. Spare the rod, spoil the child—certainly, but only for the extraverted child, who conditions with difficulty; stern treatment as a youngster may save him from psychopathic and criminal behaviour later. The same treatment for the introverted child who conditions quickly is likely to produce anxieties, phobias and other neurotic symptoms, and might lead to a permanent state of mental ill health in adult life. Conversely, therefore, *laissez faire* treatment and a maximum of freedom would be advocated for the introverted child. I suspect that the same dichotomy applies to criminals and that we should indeed fit the punishment not to the crime, but to the criminal. This nowadays is probably a very commonplace statement, but I would suggest that it acquires meaning only when we know what are the relevant personality traits of the criminal to which the punishment must be suited. If the theory here described is correct, then we may at long last have available a method for sorting out our criminal population into types responding differentially to different types of treatment.

I would like to make one last point. In antiquity

the bearers of bad news were often beheaded although they had nothing to do with causing the upset which they were delegated to report on. In the same way, I have often found that a simple statement of scientific fact which is displeasing to a person may cause that person to look with disfavour upon the one communicating it as if he were responsible for these facts. You may feel that it is a great pity that human beings can be conditioned, that they resemble brute animals in this respect, and that rational thought plays so little part in so much of their conduct. If indeed you feel that way, and I know that many people do, I beg of you to realise that though I may be the bearer of bad tidings, I am not responsible for the facts being as they are. The scientist is concerned first and foremost with discovering the facts; Society as a whole has to decide what, if any, use has to be made of these facts. This process of fact finding and fact digestion requires an intermediary process, that of fact dissemination, and I have tried in this lecture to aid in this process of communication by describing some facts of modern research on conditioning. I believe that these facts and theories are important and may be useful in dealing with some of our social problems; whether they shall in fact be so used, and the necessary research financed and supported to the requisite extent, depends in part on the degree to which they become understood and accepted by the man in the street.

SCIENCE APPLIED



High Pressure Steam Distributor Drums manufactured by English Steel Forge and Engineering Corporation Ltd., Sheffield. These are the longest one piece hollow forgings to be made in Great Britain.

INDUSTRY AND INDUSTRIAL SOCIOLOGY

By J. H. SMITH *London School of Economics*

Industrial sociology is about work and the relations between men created by the necessity of work in society. Now work has never been a popular subject; the Greeks, for example, believed that mechanical labour should be done by slaves since such work brutalised the mind and was therefore to be avoided by the virtuous élite. Some commentators, looking at the affluent but unmistakably *industrial* society in which we live, seem to feel the same. Possibly this is one reason why industrial sociology is such an infant subject and why enthusiasm for it has been slow to develop. Be that as it may, there is enthusiasm, and it is growing; and it is not confined to the academic research worker. Others are beginning to accept that social research has a necessary place in industry. Seven years ago the Department of Scientific and Industrial Research embarked upon what has since become a continuing programme of social research, Treasury-financed and carried out for the most part by universities and independent research institutions. Between 1953 and 1957 a Joint Committee of the D.S.I.R. and Medical Research Council administered funds totalling £182,000 for social research in industry, enabling twenty-eight projects to be undertaken.[1] By the standards of the more respectable sciences these are modest figures, but for British sociology they have represented a substantial shot in the arm at a crucial stage of development. In this Paper I want to throw some light on what has been happening, and to suggest what the implications of this increased activity in social research are likely to be for industry as a whole.

The Scope of Industrial Sociology

First of all, when the sociologist chooses to work in industry, what is he trying to find out? One question which I suppose must be anticipated is: what is the relationship between industrial sociology and industrial psychology, and don't they overlap at many points in their interests and activities? This is certainly a question to occur to anyone who has heard of the study of 'Human Relations' in industry and who may have concluded that 'Industrial Sociology' seeks merely to provide a more respectable academic title for a rather suspect activity.

Objections of this kind are best disposed of by trying to state simply what industrial sociology is about. To say that it is concerned with the social aspects of work is not particularly helpful unless we can indicate in some detail what these aspects are. To do this properly involves considering research examples, but let us say for the moment that some typical studies deal with the problems of getting people to work together as a team, the problems of allowing subordinates an appropriate degree of independence in the large-scale enterprise, the problems created by the impact of technical and/or economic change on the livelihood of a community. We can say further that the sociologist approaches most problems through the study of groups and group relations, and that this provides us with a simple classification of the problems with which industrial sociology deals, as follows:

1. The problems of men working together in small groups.
2. The problems of getting these groups to work with one another in the framework of one organisation.
3. The place of these groups in the local community or in society as a whole.

Though by stressing his interest in groups we narrow down the field of research, the sociologist

who studies behaviour in industry still seems to be tackling a surprisingly wide range of problems. He would claim, however, to be interested chiefly in identifying the social relations characteristic of industry; and by adopting this standpoint in all his investigations—however diverse they may appear—to be able ultimately to develop a systematic account of social behaviour in industry. Now this systematic account remains an objective rather than a concrete attainment; but a consideration of some recent literature in this field does show that if the sociologist still seems a very long way from the goal of developing laws of social behaviour, he can at least display a certain sophistication in describing the complex patterns of life at work; and furthermore in demonstrating the interaction between social behaviour in the factory and in the world outside.

Let me illustrate this by showing you how the sociologist studies the mining industry. In the past ten years, work has been done in each of the three main areas I have distinguished.

First, the sociologist has been studying the social relations between teams of miners working at the coal face and how these relations are shaped by the technical requirements of the task—for example whether the miners work in small, intimate teams (as under the old Pillar and Stall System) or in large, relatively impersonal gangs (as under the Long Wall System). He has also related this to their attitudes to work and work performance, as members of the Tavistock Institute of Human Relations have been doing for a number of years.[2] In the second area of study, he has been examining the distribution of authority and other administrative problems arising between the newly created levels of management in the nationalised coal industry, as in several studies by the Acton Society some years ago.[3] Finally, in the third area, he has been examining the disruptions of community life and the human problems of redundancy and transfer created when collieries and entire coalfields are closed down in the interests of technical efficiency: this is what social research workers from the National Coal Board itself have recently been doing.[4]

If these lines of inquiry have one thing in common it is a notion or concept of systems of social relations which are created because there is a mining industry. These systems are complex, and involve large numbers of people; some are created by the division of labour within the industry itself, i.e. the relations among and between face-workers, deputies, mine-managers, clerks, divisional and headquarters administrators; while others arise because of the effect of the industry and its workers on community structure, i.e. the family life of the mineworker, his political outlook and its influence locally and nationally. All these phenomena can be viewed as social systems, or as parts of social systems; and this is principally why the sociologist is interested in them. This should make clear the essential difference between industrial sociology and industrial psychology: the former is marked by the emphasis on groups and 'systems' of social relations as expressions of human behaviour, while the psychologist tends to concentrate on the individual and his adjustment to work. The sociologist looks beyond the behaviour of workers or managers as individuals to the systems of social relations in which they participate—the work group, the organisation of the enterprise that employs them, the community in which they live, even the national ties of union and political party which they acknowledge. All these, he argues, are relevant to the systematic study of industrial behaviour.

Industry's Interest in Social Research

Putting it at its simplest then, the sociologist looks beyond the worker himself to the social relations created by industry. Why has industry become interested in his work? One answer is that the sociological approach escapes some of the limitations of industrial psychology. Indeed, industrial sociology began as a breakaway from that subject which in its traditional form, dealt with the relation between industry as a physical environment and the workers' mental and physiological capacities: it focused attention on the worker as an isolated phenomenon, and certain characteristics of his performance which were important to management, such as 'fatigue', 'monotony' and 'incentives'. Each of these characteristics was treated as a distinct entity to be analysed separately.

But in the 1930's the argument began to be put forward that mental and bodily 'states' such as fatigue required explanation in terms of the *social* characteristics of the world of work. For example:

> It is too fatally easy to conclude that because we have a word 'fatigue' there must be a simple thing

or fact that corresponds with it. . . . The industrial investigator is constantly forced in his inquiries to take account of many factors in a complex situation; wherever the general effect is unsatisfactory to the worker and to industry, he sets himself to discover the nature of the disequilibrium and the nature of the interference.[5]

Those who set off on these new paths of inquiry were pioneers in the sociological analysis of industry; and the author of the passage quoted was foremost among them—the late Elton Mayo of the Harvard Business School. This is not really the place for an assessment of Mayo's contribution to the subject; but since we are concerned with industry's recognition of the value of industrial sociology, it must be said that his writings on the famous Hawthorne experiments did much to convince industry of the need for sociological research. What is more in doubt is his reputation among sociologists, which perhaps indicates the growing maturity of the subject: there are now two distinct schools of thought on the nature and scope of the problems to be studied by industrial sociology, which are pro- and anti-Mayo respectively. This controversy need not detain us here, except to note that like many great pioneers Mayo gave his subject a distinctive shape, so that many of those who followed him have found themselves handicapped by the impression Mayo gave industry of sociology. Though the Hawthorne studies examined several features of the social structure of the Western Electric plant in Chicago, industry has remembered them best as demonstrations of the power of the small working group. By taking part in the research the girls in the Relay Test Assembly Room became conscious of their identity *as a group* helping the company, and this was held to explain the fact that their output increased steadily over what remains the longest continuous experiment of its kind: 'physical factors' were ruled out as an explanation since repeated variations in physical environment had no observable effect on output. By contrast the men in the Bank Wiring Room helped themselves *as a group* rather than the company, but in this case it was done by a systematic restriction of effort (though against their apparent financial interest), which they maintained by elaborate expressions of approval and disapproval of each other's behaviour.[6]

Now it is no exaggeration to claim that the public reputation of industrial sociology owes nearly everything to these particular experiments: certainly they were a great influence in getting industry to allow facilities and to support research. Why did they prove of such interest to industry? Undoubtedly one attraction was the prospect of finding a scientific solution to the problems of workers' response to managements' ever present pressure to work more efficiently. This attraction was heightened by the claim that 'good' or 'satisfactory' human relations made for greater efficiency and productivity: though here it must be acknowledged that no consistent evidence has been presented that this is so–and there is a good deal of common sense observation to the contrary. Despite this, the possibilities of exploring and utilising this alleged connection between happiness and high output have had a powerful appeal to managements wishing to be progressive as well as profitable. Not everyone would term this, progress: some of those who believe that Mayo had established the connection beyond doubt have been haunted by the spectre of managements stealthily manipulating workers' behaviour for their own purposes. But these fears seem to overrate considerably the possibilities of using sociological knowledge in this way: it is likely that splitting the atom was child's play compared to the problem of dividing and manipulating a closely-integrated group of workers.

Industrial sociology came to be accepted because Mayo's work convinced industry that the study of group behaviour (as distinct from the studies of individual behaviour in conventional industrial psychology) was necessary to the solution of the riddles of conflict and social inefficiency in industry. This success, however, has obscured the fact that the sociologist's interest in industrial behaviour extends far beyond the study of human relations in small work groups. Mayo himself is on record as emphasising the need to study the 'total pattern': which can mean nothing else than the study of social relations in industry as a whole and their effect in society. As the world in which we live is increasingly shaped by industrial forces, it can be argued that the study of social relations in industry cannot properly be separated from a study of the structure of industrial society itself. Indeed, some sociologists would now say that studying industry is an important way of learning about our society. The age of Mayo, and of the Hawthorne

Experiments, therefore, has been superseded by a phase of development in which sociologists are showing interest in the widest possible range of industrial phenomena, and not merely in the social relations within work groups.[7]

Some Recent Studies

I think I have now said enough to explain why sociologists have become increasingly interested in industrial studies and why industry itself is interested in what they are doing. It may be asked why the rate of growth in the past ten years has been so rapid. The immediate causes are obvious enough; full employment, strong trade unions, the development of social consciousness on the part of management, the increased popular interest in the social sciences, have all played a part. But it ought to be mentioned that this rapid growth would not have been possible had there not existed approaches to the study of social structure and institutions which provided well-tried concepts of social behaviour. The nineteenth-century classic writers in sociology such as Durkheim, Weber and Spencer were the first to consider the place of industry in the structure of society, and pioneered lines of inquiry which others are only now beginning to follow.

In developing research in industry, then, the sociologist has been drawing on his intellectual inheritance as well as developing the new lines of investigation traced out by Mayo and his colleagues. For an overall impression of what has been done, let me use the classification of industrial studies I suggested earlier to give some illustrations of research carried out in Britain over the past ten years. To begin with, studies of men working together in small groups. I have already mentioned the Tavistock Institute's concern with the effect of different technical systems of mining on social relations among mineworkers at the face. The Institute is developing what it calls a concept of 'socio-technical' systems, in which relations in work groups are viewed as the result of interplay between technical and social factors.[8] The influence of social factors in the systematic restriction of output—a principal concern of the Hawthorne studies—has been subjected to detailed examination in British factories for the first time by research workers from the Department of Social Anthropology at Manchester University.[9]

Organisation problems—the second area of study—have received an increasing amount of attention. Consideration of the optimum size of unit, previously seen in economic terms alone, has now been enlarged to include sociological factors; are there penalties, it is being asked, attached to 'excessive' size which are measurable in terms of increased labour turnover and absenteeism, or reduced effort and managerial inefficiency? Some interesting but inconclusive work has been done on this, largely of a statistical nature: I would mention in particular that of Prof. Revans of the Manchester College of Technology.[10] Despite the lack of any clearly-established connection between large operating-size and social inefficiency, I believe studies of this kind have been important in drawing attention to the sociological aspects of 'size': or putting it in terms I have already explained, in making a case for separate analysis of the social system of the large enterprise. Support for such studies has been added by a growing curiosity about all those factors which may be said to determine the shape of management structures. At one time the sociologist was content to limit his comments on this question to what has since become a commonplace distinction between 'formal' and 'informal' organisation, i.e. between the relations prescribed for managers by the formal organisation chart and those actually established by the ties of specialisation, friendship, departmental rivalry and so on. Important though this distinction is as a first step towards the understanding of management behaviour, it had one undesirable consequence in that for several years formal organisation was treated by sociologists as being of little significance. Only recently has it been generally accepted that management organisation is essentially a system for achieving economic and technical objectives; and that although the sociologist is right to emphasise its social characteristics, they cannot be explained in isolation from the economic and technical environments in which companies operate. How many managers there are, the range of specialisation they represent, and the speed with which they must be co-ordinated: these are critical questions in interpreting a management system. All have significance for the social world in which the manager must work, but each is affected by the technical complexity of the product, and the way in which it is marketed. The extreme examples are obvious enough: there are more

managers and a bigger job of co-ordinating them in a large-scale car firm operating in world markets than in a small firm making, say, cricket bats or bowler hats. But between these extremes, the logic of management organisation is often difficult to perceive, as Miss Joan Woodward's recent path-breaking study has shown.[11] She analysed the management structure of 100 firms and concluded that there was a surprisingly diverse range of solutions to the problems of management organisation, but that the influence of technology was everywhere apparent. We now have the suggestion that a typology of management structures needs to take as its starting-point the technical problems management must solve, rather than the view of management theory that there are management principles of established validity. This is an important subject for further investigation. We at the London School of Economics are making a long-term study of supervisors; in which we are trying, through comparative study of factories with differing technologies, to identify the elements of the supervisory role and how they are determined.

Before leaving studies of management organisation I must mention the work of Mr. Tom Burns and his colleagues at Edinburgh University on the adaptability to change shown by managers in an industry—electronics—in which innovation is both frequent and necessary.[12] Their finding that the organisation chart may provide a refuge for managers wishing to avoid the consequences of change gives further support for revision of the conventional solutions to management problems embodied in the 'line and staff' theory. The application of this current research in the anatomy of management may well prove to be sociology's most significant contribution to industry's practical problems in the next decade.

The final category of studies to report on are those concerned with the place which industrial groups and institutions occupy in the wider society, and their influence on social behaviour generally. The social origins of managers and their educational background affords a fairly simple example; the effect of the part-time employment of the mother on family life, a rather more complicated one. Both subjects have found a place in the D.S.I.R. programme.[13] Designing and executing studies of the industry–society relationship poses formidable problems of method and analysis, which accounts for the relatively small number on record. It is difficult to find a middle point between on the one hand, the broad semi-journalistic survey of trends, such as W. H. Whyte's stimulating suggestion that as the power of organisations multiplies, American society is made up increasingly of conformists rather than individualists[14]; and on the other the laborious excavation of minutiae, such as who, what grades and how many among a firm's employees belong to the local bowls or tennis clubs. Given the present level of knowledge and of methodology, detailed explorations of this kind are probably only made satisfactorily in the setting of a relatively small community dependent on one industry. The principal examples we have of such communities—coal, steel, and the docks—have certainly not been neglected by the research worker. Change has been a favourite theme. Where the majority of families in a community both get their living from, and in many respects have their pattern of life determined by, one industry, the social consequences of industrial change are fairly easily identified and assessed. The nationalisation of coal, the ending of casual employment in the docks, the great technological changes in the process of steel-making have all been studied: and in each case, the focus was necessarily wide, since these changes could not be investigated without considering their effect on social relations outside the pit, the steel-works or the dock gates.

The investigation of change, particularly the social consequences of technical change, has an obvious practical slant, and for this reason has proved attractive both to investigators and to grant-givers (the Foundations as well as the D.S.I.R.). But it has another attraction for the sociologist, if he pursues the objectives I suggested earlier. Any thorough assessment of the social impact of industrial change must endeavour to view the social system affected as a whole. Probably the most successful attempt in this direction has been Liverpool University's work on technical change in the steel industry, in which attention was paid to the effects of change on work groups, on management and trade union organisation, and on local community structure.[15] Where such changes have measurable effects, and where the community they influence can be successfully delineated, there is much to be said for research of this kind from both the theoretical and the practical point of view.

The Practical Contribution of Industrial Sociology

The studies described have one common characteristic. None of them could have been undertaken without generous co-operation from industry. Some see this as sufficient evidence that practical benefits for management will follow, since it is so often assumed that management decisions are made on no other basis than that of naked self-interest. Indeed management's enthusiasm for social research has been interpreted as a sign that a 'managerial sociology' is in the offing in which the mysteries of social science will be utilised to seduce the worker into uncritical acceptance of his master's actions. I have already suggested that this is an exaggerated fear. The possibilities of manipulation may certainly exist, but workers have never been slow to recognise such attempts and the findings of social research can be noted by trade unionists as well as managers. In any case, I feel that the emphasis on sociology as a source of industrial techniques is misplaced. It is customary, when looking for the 'practical' significance of research, to single out those findings which can be expressed as formulae to be applied as required. But there is very little in industrial sociology so far which amounts to prescription: indeed, its chief recommendations are rather what *not* to do. No doubt, as more research is done, there will be findings which can be applied directly, particularly in industrial training. My fear is that to emphasise practical applications of this kind overlooks what may well prove sociology's most effective role from industry's point of view. We are told that as industry develops—and in particular as automation advances—management will be more and more a 'thinking' process. If this is true, then industry stands to benefit from understanding the nature of sociology as an intellectual discipline; in other words, by understanding what it has to teach about *how* to think rather that *what* to think. I myself believe that the growing interest in industrial sociology is a recognition of this—though perhaps an unconscious one. Sociology can help to make better managers, supervisors and trade unionists not so much through predicting the boiling-point of the foreman as by promoting a general awareness of the social characteristics of work.

We already have an example of this influence in our thinking about organisation problems. Largely as a result of work done by social scientists during the past thirty years, we are getting used to considering industrial organisation as a human and a social problem. This is no mean feat when for the better part of two centuries people have been in the habit of viewing the problems of industrial organisation in terms of money, machines and markets—and hardly at all in terms of men.

I am not suggesting that social research in industry should forsake the particular for the general, or that sociologists should refuse to investigate problems of vital concern to industry. There is scope for many different kinds of approach, and findings of general sociological interest can emerge from 'problem-centred' studies, as the D.S.I.R. programme shows. But I think it is now up to the sociologist to convince those in industry that they have much to gain from a wider understanding of the nature and potentialities of his subject as an academic discipline.

In particular, it has an important function which is rarely discussed in its industrial context. Human values and their preservation have always been a concern of sociology, and industry's awareness of them is a critical factor in the moral life of contemporary society. What effect does modern industrial organisation have on the life experience and personality of the individual? How do the values of the dominant industrial institutions—the large-scale enterprise, the monolithic trade union—affect social values in general? Because of their existence, do we nowadays place a disproportionate emphasis on conformity? Do we, in seeking so enthusiastically what industry has to offer towards a better standard of life, overlook what it may subtract as well as add in the sum of human improvement?

These are questions on which the sociologist can have something useful to say; not by trotting out assertions, but by trying to assemble the facts for us all to consider. That is why we should resist attempts to confine our research to matters which management—or for that matter, the trade unions—regard as of immediate practical significance. Certainly sociology has something to offer in that direction: but its most important contribution to the problems of an industrial society may well

depend on its capacity to promote reflection and rationality among those whose conflicts and prejudices it is now studying.

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AN EXPERIMENT IN FIELD ARCHAEOLOGY*

By Dr. P. A. JEWELL *Department of Animal Husbandry, Royal Veterinary College, N.W.1.*

Last year, in the summer of 1960, a new sort of experiment in archaeology was initiated. Instead of excavating an ancient earthwork a team of volunteers built a new earthwork, which now stands, a bank and ditch of gleaming white chalk, on Overton Down in Wiltshire. The purpose of the earthwork is to enable archaeologists to record from the beginning the sequence of changes that result in the denudation and silting up of such a structure. This information will be used to help in the interpretation of the excavation of ancient monuments, most of which, we suppose, were subjected to a similar process of natural decay at some now distant time in prehistory.

It was decided to build an earthwork consisting of a straight ditch and bank which would be a simplified model of the type of structure encountered in hill forts, barrows and henge monuments. Nearly two years were spent in planning the earthwork, choosing a site and gathering materials together. In addition the suggestions of both archaeologists and natural scientists were collated so that the earthwork might yield the maximum of information.

The site chosen is in the Fyfield Down Natural Nature Reserve; it is a high and exposed part of the chalk downland. The soil above the chalk is little more than a foot deep, the turf being separated from the decomposing top of the chalk by a layer of accumulated small flints. The whole area was carefully surveyed and the earthwork is oriented so that its long axis is on horizontal ground. This was done in order to avoid any slope effects along this axis, such as rain water flowing towards one end of the ditch.

The plan provided for a ditch ninety feet long, ten feet wide at the top with the sides battered to give a width of eight feet at the bottom. When dug out and heaped into a bank, loosened soil and chalk occupies a considerably increased volume; this had to be calculated in advance so that a berm four feet wide could be left between ditch and bank. Finally, before digging was started six steel tubes, each nine and a half feet long enamelled black and white in one-foot bands, were set at intervals along the spine of the future bank. These tubes were set vertically in small columns of concrete set two feet into the solid chalk; they form permanent and immovable datum rods from which all future soil movement can be measured.

All the construction was carried out with hand tools, which allowed fine control over the manner of working and bank building. The zeal of the volunteer force was so great that it soon became clear that at least as much time would be spent in laying out, measuring and photography, as in the actual work of soil shifting.

First the turves from the ditch, cut in one-foot squares were stacked to form the central core of the bank. The soil and flints from beneath the turves were then heaped on top of this long stack to give a low mound, triangular in section, eight and a half feet wide at the base and two and a half feet high. The rest of the bank was built of chalk from

* This report summarises the work of the British Association Committee on Archaeological Field Experiments set up in 1958, its members being: Dr. G. W. Dimbleby (Chairman), Dr. P. A. Jewell (Secretary), P. Ashbee, Professor R. J. C. Atkinson, Dr. I. W. Cornwall, Dr. G. Dury, Dr. V. B. Proudfoot and Mrs. P. M. White (Assistant Secretary).

the ditch, and was raised in three distinct phases, the material for each phase of bank building coming from an arbitrary, but carefully levelled, layer in the ditch. The bank thus retained its basic triangular cross section, although the apex of the bank was flattened to provide a working surface. The interfaces between soil core and chalk, and the two interfaces between the chalk layers, were marked with a scatter of roadstone chippings, each with chippings of a different rock. The chippings used were Penlee hornfels, Pyx granite and Criggion grey-green basalt. Each completed layer of the bank was raked and levelled to a precise profile, this being achieved in a simple way by the use of taut wires and strings attached to the upright enamelled tubes. The layers of the ditch were defined by boning, but its final, cross sectional, profile was perfected in a more elaborate way. A template having the shape of the required cross section of the ditch was built of bolted metal struts. The sides and bottom of the ditch were then trimmed so that with a small clearance the template, guided by a taut wire, could traverse the entire length.

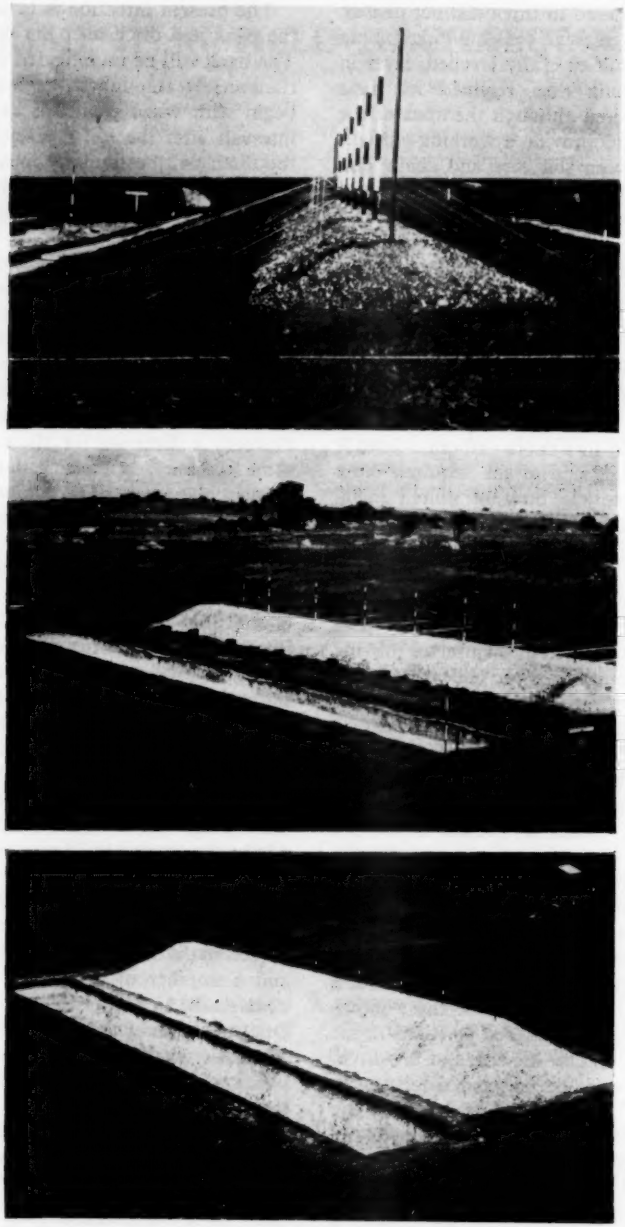
The permanent upright tubes, and the precision of bank building, will in themselves provide the basis for measurements of soil movement. Deformation of a series of polythene tubes set vertically within the bank will be used to measure the movement of material in the various layers of which the bank is built. In addition two types of marker were incorporated in the structure. The first of these were pieces of broken flower-pot which were scattered at random all over the site before any work began. These are intended to simulate 'pre-earthwork' pottery sherds, and the interest will lie in seeing what position they have reached in and on the earthwork. The other markers are small pottery discs, imprinted with a serial number before firing; 500 of these pieces were placed in precisely measured positions in the bank, on the berm, and on the edges of the ditch. One other point should be mentioned relating to the preparation of the site before building the bank. Lycopodium spores were dusted over the area to simulate a rain of pollen grains; in addition powdered charcoal was scattered over the grass surface; the movement of these minute objects within the soil is one of the changes to be measured in the coming years.

The present intention is to measure changes in the bank and ditch over the next hundred years. The bank will be investigated by cutting trenches transversely through it, at frequent intervals to begin with when change is rapid, but at longer intervals after the soil has settled. The silting of the ditch will be similarly measured. In this way it is intended to build up a picture of the rate and extent of soil movement and displacement in the structure as a whole.

As already stated, all the work of construction was carried out with hand tools, but not all of these were modern pick and shovel. A complete section of the ditch and bank, fourteen feet in length, was dug with primitive tools, that is, with antler picks, shoulder-blade shovels and wicker carrying baskets. Digging this section provided not only a diversion for the volunteers, but also some extremely interesting data on the efficiency of primitive tools. The antler picks proved remarkably resilient and could be used either with swinging blows like an ordinary pick, or by battering the tine into the chalk with a wooden mallet. No pick was ever broken, only the striking points of the tines became splintered and shortened by the loss of chips. The shoulder blades were inefficient shovels and created the real bottleneck in the work. The overall efficiency of the primitive tools, in terms of time taken to shift a given volume of rock, proved to be one-third that of modern tools; nevertheless their effectiveness was amply demonstrated. The figures obtained from this work-study will be valuable as a guide to the manpower required to build earthworks in prehistoric times.

One further study has been added to the project, and that is an investigation of the fate of buried objects in the soil. A variety of materials is involved and a number of samples of each material has been placed in two contrasting soil environments. One position is on the present turf surface, beneath the turf stack, at the centre of the bank; the other position is a wholly chalk environment higher in the bank. The sets of objects are so placed that they will be recovered in the planned trenches that are to be cut at future intervals of time.

Eight different materials are involved. Billets of oak and hazel, charred and uncharred, provide four variables for direct comparison of the effects of burial, and for a similar reason cooked and



Three stages in the construction of the earthwork. *Top:* the first stage with the turf core covered with subsoil. The turf stacks are plank supports. The lower line of strings mark the profile for the first layer of chalk. The upper strings support the vertical polythene tubes. *Middle:* first layer of chalk completed. *Bottom:* the finished earthwork.

uncooked sheep bones have been buried in pairs. Cremated human bone was buried as a mixture of pieces and fragmented bone dust to determine losses due to natural wastage and to failure during excavation to recover buried material of such small size. Samples of wool, cotton and linen, form a group of objects, as also do leathers tanned in five different ways. Of the latter only the bark-tanned leather compares closely with leathers used in early times; data on the changes in the various types of leather may, however, be of value in interpreting the chemical processes at work in the different environments beneath and in the bank. Fresh fractured flints are included to study the development of patina and at each site pieces of pottery have been placed that are made from a known clay-type and were fired at a fixed temperature. Finally pieces of human bone of known blood group are included in the sets of objects; from the subsequent excavation of this material, it is hoped to obtain data on the stability of the blood-group proteins under different environmental conditions.

A great deal of useful information has already been gathered from this first experimental earthwork and there is every reason to be confident that the effort expended on it will be amply rewarding. It can, of course, only give direct information on the weathering effects of a local climate on a particular soil type, namely chalk downland. The Research Committee plan, however, to build two more earthworks, one on acid heath, and one on a loam in a high rainfall region, to provide comparative data from these contrasting environments.

Acknowledgements

Permission to build the earthwork on Overton Down was given by Mr. G. E. Todd and the Nature Conservancy. Money to aid the work was granted by the British Association, the British Academy, the Society of Antiquaries and the Nature Conservancy. Mr. F. Swanton provided a camp site and both he, and the Ministry of Works (Avebury), gave us much material assistance. Mr. H. Hemsley, Regional Officer of the Nature Conservancy, assisted with many organisational details. The steel tubes were given by Accles & Pollock Ltd., through Tube Investments Ltd., and were enamelled by the Rustless Iron Co. Ltd., through the co-operation of Mr. H. Whitaker. The Corrosion Advice Bureau of the British Iron and Steel Research Association helped with a number of problems. Roadstone grit was given by the Amalgamated Roadstone Corporation Ltd. Other materials were given by the British Leather Manufacturers' Research Association, the British Cotton Industry Research Association, and the Wool Industries Research Association, these through the co-operation of Mr. L. Biek of the Ministry of Works Ancient Monuments Laboratory. Deer antlers were provided by the Duke of Bedford, Capt. C. E. Lucas, the Zoological Society of London and the Castle Museum, Norwich. We wish to express our thanks to all these organisations and individuals. Mrs. P. M. White has acted as Honorary Assistant Secretary to the Research Committee and has given most valuable help both in the preparatory work and in organising the field work.

NEW BOOKS FOR THE GENERAL READER

The following notes are published by courtesy of the National Book League. They will be reprinted in the next annual supplement to SCIENCE FOR ALL, *an annotated reading list published for the N.B.L. by the Cambridge University Press.*

GENERAL

Clark, Robert E. D. CHRISTIAN BELIEF AND SCIENCE: A RECONCILIATION AND A PARTNERSHIP. *English Universities Press*, 1960, 12*s.* 6*d.* 160 pp. (215)

Tarranto, Laurence G. LEARN SCIENCE THE EASY WAY. *Chambers* (*Learn the Easy Way*), 1960, paper, 8*s.* 6*d.* 342 pp.

One of a series of popular American textbooks for home students. This introductory book covers a wide field by way of appetiser to the fuller treatments of Biology and Chemistry (see under relevant headings). Its preface suggests that the reader should 'skip, hop and jump through the pages, lighting long enough to digest facts that catch your eye'. Tests and essay questions are provided. (500)

MATHEMATICS

Hogben, Lancelot. MATHEMATICS IN THE MAKING. *Macdonald*, 1960, 50*s.* 320 pp. Colour and black-and-white illus. throughout text.

'This book', according to a note on the jacket, 'reviews the history of mathematics with the express purpose of familiarising the intelligent reader . . . as simply and painlessly as possible' with 'the mathematical techniques which modern science employs'. It is very fully illustrated. The text is not easy; its chief appeal will probably be to those with a substantial grounding in mathematics, and its most useful function that of illustrating the practical uses and intellectual attraction of mathematics through the ages. (510)

Land, Frank. THE LANGUAGE OF MATHEMATICS. *Murray*, 1960, 21*s.* vii, 264 pp. Diagrams.

This book 'assumes an adult outlook and some mature interests, but presupposes no more than an elementary knowledge of mathematics'. Literate readers with a desire and sufficient determination to join the ranks of the numerate will find it rewarding. Though somewhat uneven, it is a useful contribution to bridging the gap. (510)

PHYSICS

Massey, Sir Harrie. THE NEW AGE OF PHYSICS. *Elek*, 1960, 42*s.* 342 pp. Colour frontis. 12 half-tone plates, text figs.

This is tough reading, for those who have passed their 'A' level in physics rather than for the average 'general reader'. Professor Massey has, however, so far as possible avoided technical terms. The book falls into three main sections, the first concerned with atoms and the structure of matter, the second with the atomic nucleus and with the behaviour of matter at very high energies, the third with phenomena on a very large, as distinct from a very small, scale. (530)

Valentine, J. M. TEACH YOURSELF ATOMIC PHYSICS. *English Universities Press* (*Teach Yourself*), 1960, 7*s.* 6*d.* 192 pp. 24 line illus.

For the home student who has already mastered the basic principles of classical physics. (539.7)

CHEMISTRY

Carlin, John J. LEARN CHEMISTRY THE EASY WAY. *Chambers* (*Learn the Easy Way*), 1960, paper, 8*s.* 6*d.* 412 pp. Diagrams.

One of a series of American textbooks for home students. Not quite so successful as LEARN BIOLOGY THE EASY WAY (*q.v.*). It is questionable whether there *is* an easy way of learning chemistry away from the lab. bench. (540)

ASTRONOMY

Hoyle, Fred. THE NATURE OF THE UNIVERSE. 2nd edn. *Blackwell*, 1960, 8*s*. 6*d*. 103 pp. 5 half-tone plates.

A brilliant short book, based on broadcast talks delivered in 1950, now brought up to date in the light of research over the past decade. The chapter on the origin of the planets has been completely rewritten. The author is Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. (523.1)

Smith, E. Graham. RADIO ASTRONOMY. *Penguin* (*Pelican Original*), 1960, 7*s*. 6*d*. 265 pp. 16 pp. plates, diagrams.

The comparatively new science of radio astronomy is here defined as 'the study of heavenly bodies by the reception of the radio waves which they emit'. This very lucid exposition, written with a minimum of technical expressions, 'attempts a survey of the whole of this wide subject' and 'is aimed throughout at the interested layman who wants to know what is happening on one exciting frontier of science'. (522.6)

GEOLOGY

Edmunds, F. H. GEOLOGY AND OURSELVES. 2nd edn. *Hutchinson*, 1960, 30*s*. 256 pp. 12 half-tone plates, 14 text figs.

This is a revised edition of a book first published in 1955 (SCIENCE FOR ALL, p. 78). Its aim is 'to show how the science of geology enters into our everyday life rather than how geological structures, as such, affect us'. After a summary of the history and main branches of geology Mr. Edmunds deals in successive chapters with surveys and maps, geophysics and geochemistry, bored wells and trial holes, water supply, building materials, civil and structural engineering, coal, ores, mineral oil and natural gas, agriculture and town planning. This is a substantial and authoritative work but technical terms have been avoided as much as possible and explained where necessary, so that it will appeal to the serious amateur as well as to geologists, engineers and economists. (550)

BIOLOGY

Hartman, Harold M. LEARN BIOLOGY THE EASY WAY. *Chambers* (*Learn the Easy Way*), 1960, paper, 8*s*. 6*d*. 442 pp. Diagrams.

One of a series of American textbooks for home students. It claims to provide 'a basic, simply phrased summary of all that science knows today about living things', presented in eleven 'units'. Tests and essay questions are provided. (574)

EVOLUTION

Brodrick, A. H. MAN AND HIS ANCESTRY. *Hutchinson*, 1960, 35*s*. 256 pp. 16 half-tone plates.

A clear and simply stated review of the evidence of man's evolution in different parts of the world. Useful bibliographies are provided at the end of six of the seven chapters. (569.88)

ZOOLOGY

Leutscher, Alfred. TRACKS AND SIGNS OF BRITISH ANIMALS. *Cleaver-Hume Press*, 1960, 16*s*. 252 pp. 5 half-tone plates, many drawings in the text.

All British land mammals are included, with a selection of birds, reptiles and amphibians. Each animal is described, its distribution, movements, habitat and food habits noted. In addition to detailed description, with measurements, of tracks, other signs, such as those resulting from feeding nesting, mating and droppings, voices and ways of movement, are given. Nearly all the drawings of feet and tracks are life-size. An identification key is provided. (599)

BIRDS

Bannerman, David Armitage. THE BIRDS OF THE BRITISH ISLES, Vol. IX. *Oliver & Boyd*, 1961, 63*s*. xii, 398 pp. 26 colour plates by George E. Lodge.

Vol. IX of this splendid series covers part of the Scolopacidae—godwits, curlews, sandpipers, woodcock, snipe, phalaropes, dunlins and stints. (598.2)

Bond, James. BIRDS OF THE WEST INDIES. *Collins*, 1960, 35*s*. 256 pp. 8 colour plates (66 birds) by Don R. Eckelberry; 186 line illus. by Earle L. Poole.

An identification guide, giving technical, English, and local names, description, habitat and nidification, covering the Bahama Islands and Antilles

south to Grenada. Birds of Tobago and Trinidad will be the subject of a separate guide now in preparation. (598.2)

Koffán, Károly. BIRDS IN CAMERA. *Barrie & Rockliff*, 1960, 27*s*. 6*d*. 212 pp. inc. 156 photographs (10 in colour).

Photographs of twenty species (all on the British list) in natural surroundings, most of them studies of feeding activities, a few of birds in flight. The brief text is from the photographer's rather than the ornithologist's point of view. (598.2)

MacDonald, Malcolm. BIRDS IN MY INDIAN GARDEN. *Cape*, 1960, 45*s*. 192 pp. 98 photographs by Christina Loke. 13 in. × 9½ in.

A month-by-month record of detailed observation in the author's garden at New Delhi—courtship, mating, nest-building, the hatching and training of young birds. 'To the garden . . . come innumerable birds . . . they include . . . Golden Orioles, Indian Hoopoes, Whitebreasted Kingfishers, Blossom-headed Parakeets, Blue-tailed Bee-eaters, Green Pigeons, White-eyes, Yellow Wagtails and Golden-backed Woodpeckers . . . river birds like terns, lake birds like darters and cormorants and swamp birds like egrets, herons, storks and ibises, often fly above its lawns. . . . My visitors run the whole gamut of sizes from gigantic Sarus Cranes and Griffon Vultures to diminutive Whitethroats and Hume's Leaf Warblers. . . .' The large photographs are outstandingly good. (598.2)

Voous, K. H. ATLAS OF EUROPEAN BIRDS. *Nelson*, 1960, 70*s*. 284 pp. Frontis. 355 illus. 419 maps. 13½ in. × 10¼ in.

This is an essential reference book (and source of pleasant browsing) for anyone seriously interested in ornithology. Distribution maps, explanatory text and photographs for 419 species, classified according to the type of fauna with which they are typically associated. The text deals concisely with distribution, habitat, food, nest and movement. The photographs show birds in their natural surroundings, many at their nests. (598.2)

BOTANY

Font Quer, P. PHYSIOLOGY OF PLANTS. *Hutchinson* (*Arrow Science*), 1960, 10*s*. 6*d*.; paper, 7*s*. 125 pp. 4 half-tone plates, 33 text figs.

This sequel to ANATOMY OF PLANTS deals with the physics and chemistry of plants in seven chapters: the functions of water; the chemistry of plants; growth, multiplication and reproduction; genetics; hereditary characters; and plant movements. (581.1)

TECHNOLOGY

Beeby-Thompson, A. OIL PIONEER. *Sidgwick & Jackson*, 1961, 42*s*. 544 pp. Frontis. and 32 pp. photographs.

Autobiography of a great consultant engineer whose sixty years' experience of petroleum exploration and oilfield development began in the Baku Oilfields of Russia in 1898. (926.2)

Hammond, Rolt. POWER STATIONS WORK LIKE THIS. *Phoenix House*, 1960, 9*s*. 6*d*. vi, 57 pp. 54 diagrams.

Introduces teenage readers to the general principles and planning of power stations. (621.32)

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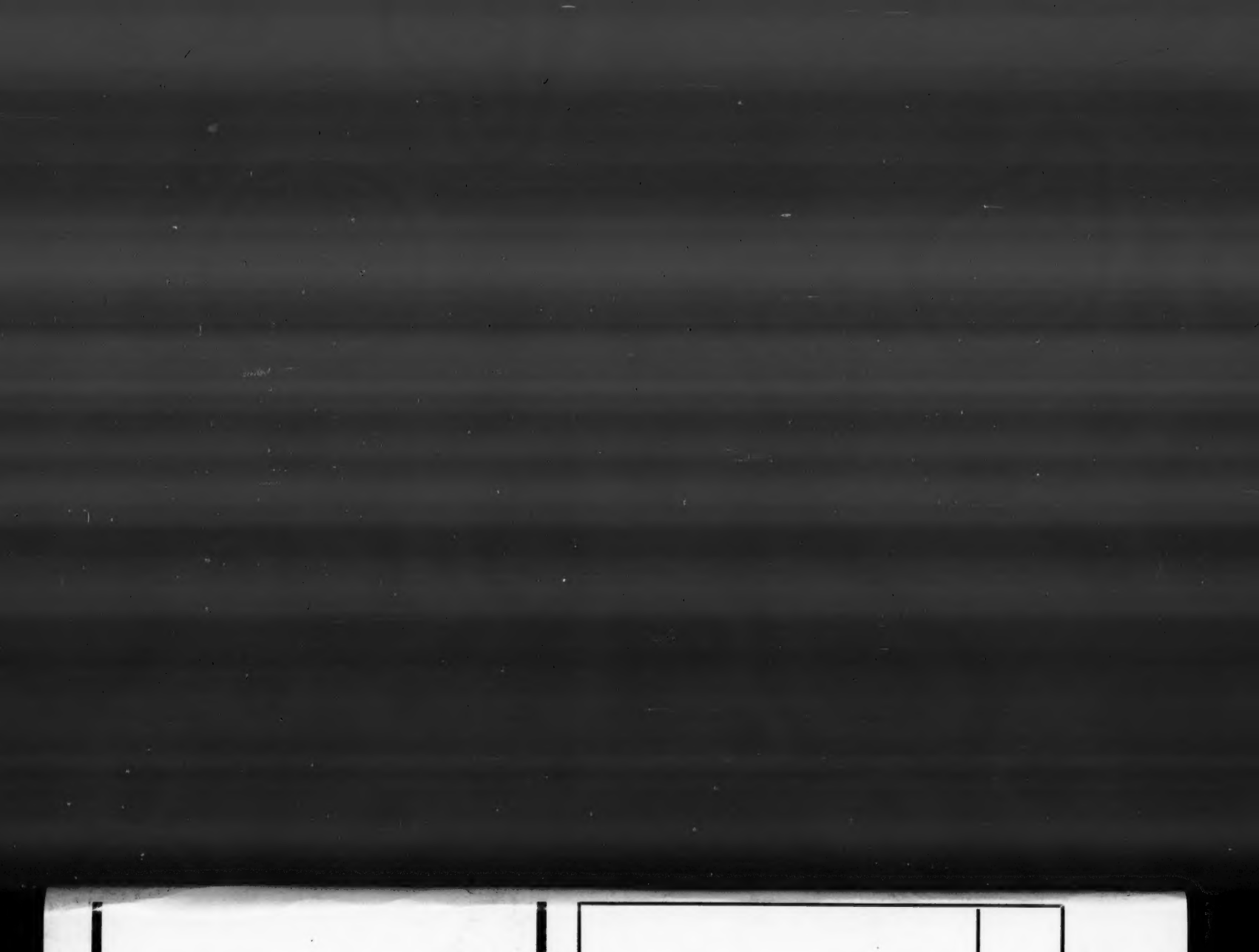
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